Capitalizing on Energy Opportunities on New York Dairy Farms

Participant Briefing Paper: Reference Document

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Dairy Power New York Summit:
Creating a Greener, Cleaner Future
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Thank you for participating in the Dairy Power New York Summit: Creating a Greener, Cleaner Future, to be held October 29-30 at the Holiday Inn in Liverpool, N.Y. The stated focus for the Dairy Power Summit is "to identify breakthrough approaches to widespread adoption of anaerobic digester (AD) technology by designing business strategies — specifically within New York — that build economic, social and environmental value."

This paper has been prepared specifically for this summit to provide a summary of anaerobic digestion (AD) in New York and to serve as reference material on the topic of AD. The paper is comprised of five chapters and an appendices section. The appendices are comprised of materials to support each of the chapters, along with a Glossary of Terms (Appendix 1) and List of Abbreviations (Appendix 2).

ACKNOWLEDGMENTS

We wish to acknowledge Mr. Thomas Fiesinger, project manager, of the New York State Energy Reseach Development Authority (NYSERDA) for the enormous effort he made reviewing several iterations of this document and for providing key inputs that added significantly to its strength and correctiveness. Additionally, we express our thanks and appreciation to Mr. Mark Stoermann, special projects manager, Fair Oaks Dairy Farm; Mr. Doug Young, managing partner, Spruce Haven Farm and Research Center; Mr. Ronald Rausch, New York State Department of Agriculture and Markets; and Mr. Stanley (Lee) Telaga, Cornell PRO-DAIRY Program, for their review efforts and helpful inputs.

We also wish to express our appreciation to Mrs. Caroline Potter, for her efforts in disseminating one of the two Cornell developed surveys to the Northeast Dairy Producer Association (NEDPA) member producers. Further, we wish to thank each producer who completed the survey and returned it to us for inclusion in the data set. Lastly, we sincerely thank the tremendous New York dairy producers for their support and willingness to collaborate on many fronts, specifically dairy environmental management.

CHAPTER 1: INTRODUCTION

1. New York, the third largest dairy state in the nation, has a proven history of environmentally responsible management.
2. The NY dairy industry is well organized and many of its dairy producers actively work to serve their dairy industry at the local, state and national levels.
3. Environmental regulatory compliance is currently one of the major challenges facing the NY dairy producer.
4. An anaerobic digester (AD) of dairy manure decreases farmstead odor and decreases farmstead greenhouse gas (GHG) emissions.

1.1 New York Dairy Industry Overview

NY has a longstanding, rich history in the dairy industry. NY has been the third largest dairy state in the United States behind Wisconsin (2nd) and California (1st) for many years, and overall a net exporter of milk and dairy products. Dairy statistics show that there are 626,000 cows on more than 6,000 dairy farms in NY, producing 12 billion lbs. in 2008 (*Hoard's Dairyman*, 2009). The average herd size is about 110 cows, with a few herds over 3,000 cows. The distribution of the number of herds by herd size range is shown in Figure 1.

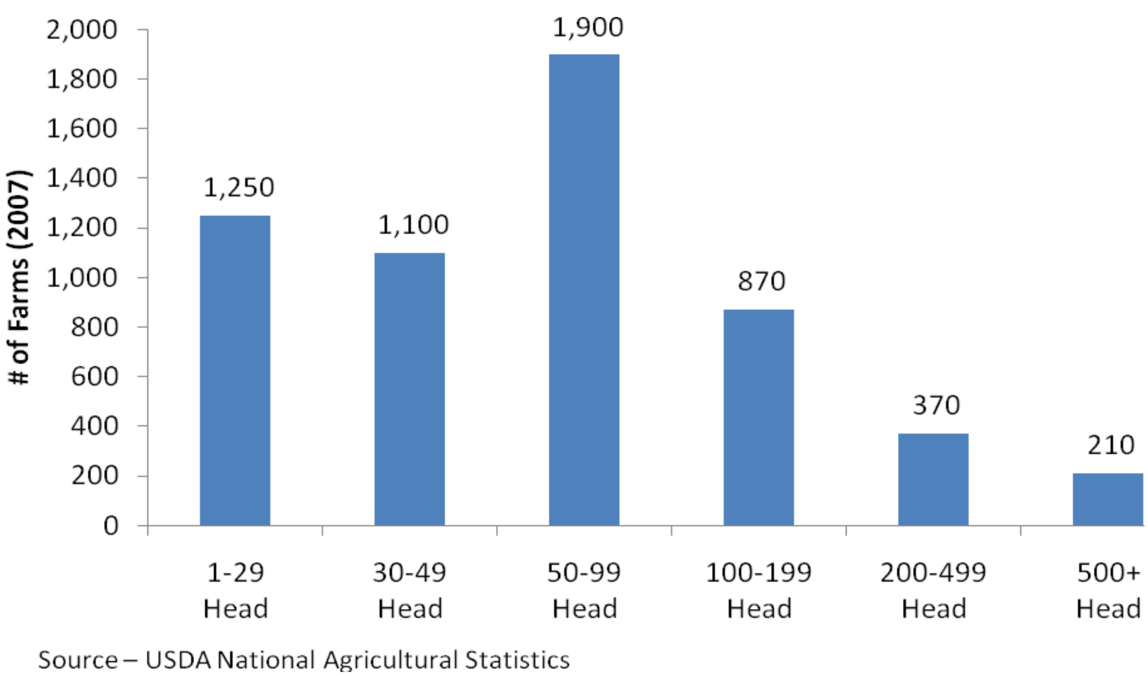

Figure 1. Distribution of New York Dairy Farms by Herd Size (2007)

Within NY, there are well-managed, sustainable dairy farms in all counties with dairy cows. The three primary milk sheds (substantial production areas) where each county in that area produces over 32 million lbs. annually, are shown in Figure 2. These areas are: Western New York (Wyoming, Genesee and Livingston Counties), central New York (Cayuga and Onondaga Counties) and northern New York (St. Lawrence, Jefferson, Lewis and Oswego Counties). Additionally, a substantial volume of milk is produced in eastern New York.

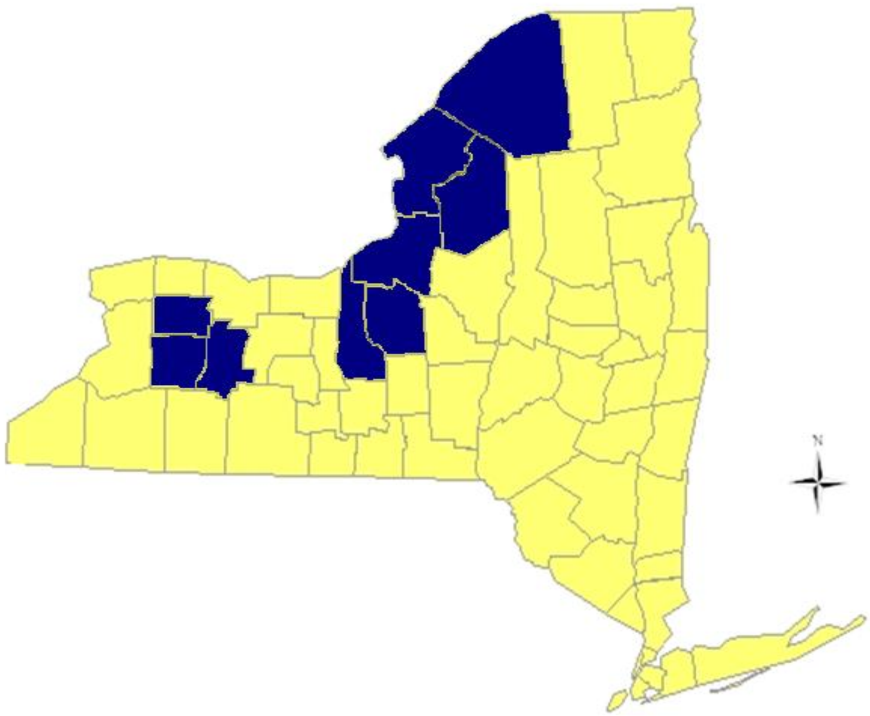

Figure 2. Federal Order Milk Marketings by County for New York (2008)

The overall success of the NY dairy industry lies in the strength of the dairy producers. There are numerous progressive, well-managed dairies that continually strive to improve their dairy businesses and as such rely on partnerships with other producers, consultants, public and private service providers, public agencies, and others.

NY dairy producers serve the dairy industry in many capacities beyond producing milk. Many producers donate countless hours of their time working in diverse capacities, including serving for the following organizations:

- Center for Dairy Excellence board of directors and Environmental Stewardship Committee
- Cornell Cooperative Extension county advisory boards
- Cornell University advisory committees
- Cornell Board of Trustees
- Farm Bureau; local- and state-level positions
- National Dairy Board
- National Milk Producers Federation board of directors
- National Milk Producers Federation – environmental task force
- New York Farm Viability Institute board of directors

- Northeast Dairy Producers Association (NEDPA) board of directors
- NYS CAFO Workgroup
- PRO-DAIRY Program advisory committee
- USDA-NRCS Agricultural Air Quality task force
- US EPA Agricultural advisory committee
- Various milk cooperative advisory boards
- County Soil and Water Conservation boards
- County Ag and Farmland Protection boards

The dairy industry is one of the remaining industries that is largely fragmented. Unlike the swine and poultry industries where vertical integration is typical, the dairy industry has independent farm owners who have autonomy to make business decisions they feel are best for their dairy. Therefore, it is important to note that, at the farm level, each dairy farm is different in layout, infrastructure, resource availability, management and farm interest in manure management systems like AD.

1.2 Environmental Compliance - Water Quality

Generations of dairy farmers have a long history of being good stewards of the land. Farmers realize that their business success and longevity is contingent on having suitable cropland to grow feeds for their cows and high volumes of quality water to water their crops and their cows alike. Farmers pride themselves on handing down their farms from generation to generation and thus want to ensure the land and water resources needed are available in the future.

In 1999, the New York State Department of Environmental Conservation (NYSDEC) initiated a Concentrated Animal Feeding Operation (CAFO) permit program for animal agricultural operations with the goal of meeting federal Clean Water Act requirements and maintaining or improving water quality of streams and lakes.

Under the newest NY CAFO permit issued in June of 2009, all dairy farms with more than 200 cows of milking age or 300 heifers will require a CAFO permit by March 31, 2010. Under the permits that expired on June 30, 2009, where medium CAFOs (200 to 699 cows or 300 to 999 heifers) were not automatically required to be permitted, there were about 450 medium dairy CAFOs and 145 large dairy CAFOs in New York (NYSDEC, 2009). All NY CAFO permits also require each farm to have a third party planner certified by the state to develop a site-specific comprehensive nutrient management plan for their farmstead(s) and fields. Many farms utilize long-term manure storage for both manure management and environmental protection purposes.

NY State Pollutant Discharge Elimination System (SPDES) permits, another requirement for some dairy producers, are typically renewed every five years. The 2009 renewal included two permit options for large CAFOs: the State-based Environmental Conservation Law permit and the Federal-based Clean Water Act permit.

1.3 Air Quality Ramifications of Manure Storage

In upstate New York, it is probably common knowledge that dairy manure stored long-term produces odorous emissions. Operative microbes that thrive in the oxygen-free environment of long-term storages produce offensive and potentially hazardous (when in a confined-space situation) gases, including ammonia (NH_3) and hydrogen sulfide (H_2S). Other populations of operative microbes produce GHG emissions, most notably methane (CH_4). Methane is reported to have a global warming potential (GWP) of 21 to 23 times that of carbon dioxide (CO_2) (U.S. EPA, 2006).

Dairy farmstead manure-based GHG from long-term manure storages can be mitigated in two ways:

1. Covering the manure storage with an impervious cover to capture and flare biogas

2. Anaerobically digesting freshly excreted manure prior to being stored long-term.

Each of these methods is discussed within this paper, with an emphasis on AD, due to its ability to not only lower farmstead GHG emissions, but also to produce a meaningful supply of renewable energy. This form of renewable energy has the added benefit of offsetting fossil fuel energy uses and can result in a reduced GHG footprint.

Chapter 1 References:

Hoard's Dairyman. 2009. W.D. Hoard & Sons Co., Fort Atkinson, WI 53538

NYSDEC. 2009. New York State Department of Environmental Conservation. Personal communication.

U.S. EPA. 2006. *Methane: Global Warming Potentials.* Web site: http://www.epa.gov/outreach/scientific.html

USDA. 2007. National Agricultural Statistics.

CHAPTER 2: NEW YORK DIGESTER STATUS AND LESSONS LEARNED

1. Thirteen of the 14 operating on-farm AD systems in NY are located on dairy farms; the other is located on a duck farm.

2. Currently, the in-place electrical generation capacity is 2,655 kW with five more AD systems under construction and 14 in the planning stages, resulting in a combined generation-capacity of 8 MW in the near future.

3. After the 19 AD systems under construction and planned are completed, NY will have an AD generation capacity of 10.5 MW.

4. Twelve of the 13 operating digesters received public money to offset capital costs.

5. The high capital cost and rather low return on investment is the major challenge to be addressed.

6. Other challenges are related to design, construction and system management.

2.1 State of Anaerobic Digesters in New York

Overall, AD as a manure treatment strategy has varied in popularity for many decades for much of the U.S. dairy industry, including the dairy industry in New York. Initial interest was sparked during and immediately after the energy crisis caused by the 1973 oil embargo when many AD systems were built to produce energy (Wright, 2001). Nationally, at least 71 systems were constructed on commercial livestock and poultry operations, but subsequent to an overall decrease in energy prices, many of these systems were abandoned. Only 25 of the 71 were still operating in 1995 (Wright, 2001) and none of the originally constructed systems are still in operation today in NY. Specific details on the technology of AD, as well as water quality implications and performing AD feasibility studies, can be found in Appendices 3, 4 and 5, respectively.

In the recent past, NY dairy farmers constructed digesters primarily as a means of lowering farmstead odor emissions with secondary goals of generating renewable energy; GHG reductions, until most recently, were not cited as a reason to construct digesters.

2.2 Digester Locations and Characteristics

The location of all AD systems currently operational, decommissioned and planned is shown in Figure 3. The digester shown on Long Island processes effluent from a duck farm; the others shown are all located on dairy farms. Most of the larger dairy farms are concentrated in the central and western part of the state, resulting in a larger number of systems in these areas as compared with elsewhere in the state.

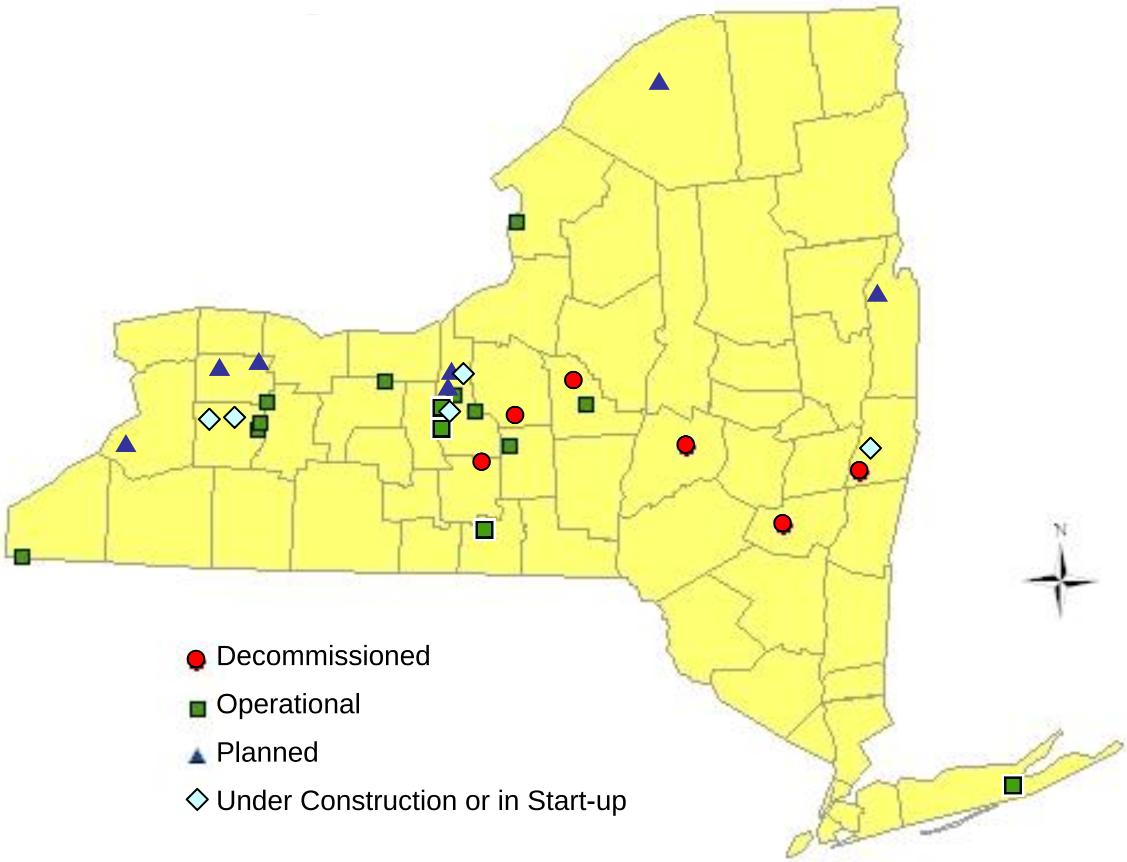

Figure 3. NY Digester locations

A snapshot of some basic aspects of each existing and currently planned AD system, provided for the purpose of a quick comparison, is shown in Tables 1 and 2. Case studies are available for most of the farms and can be accessed at: www.manuremanagement.cornell.edu. The case studies are updated periodically to reflect changes, such as animal population, management practices and system improvements.

Currently, there are 13 NY dairy farms with operating ADs constructed over the past 11 years that have an aggregated in-place electrical generation capacity of 2,655 kW. Significant public funding made available by NYSERDA and the USDA-NRCS Equip and Rural Development programs were involved in the development of these projects. All farms with currently operating digesters have had some level of grant money involved to help offset the capital and/or operational costs. As of August 2009 manure from **14,000 cows** was digested daily and the in-place generation capacity was **2.7 MW**.

Table 1. Operational AD Specifications

Farm	Farm ID[1]	Digester Type	Designer	Capital Cost ($)	Start -up	# of Milking Cows	Est. HRT (days)	Estimated Loading Rate (gal/day)
AA Dairy	1	Plug-flow	RCM Digesters, Inc.	363,000	1998	600	37	11,000
Aurora Ridge Dairy	14	Plug-flow with biogas recirculation	GHD	2,300,000	2009	1,600	22	84,000
Corwin Duck Farm	9	Complete mix	Applied Technologies, Inc. (Wisconsin)	2,200,000	2005	130,000 ducks	10	100,000
El-Vi Farms	6	Plug-flow/mixed	N/A	294,000	2004	800	10	30,000
Emerling Farm	8	Plug-flow	RCM Digesters, Inc.	N/A	2006	1,100	20	48,000
New Hope View Farm (formerly DDI)	2	Plug-flow	RCM Digesters, Inc.	984,000	2001	850	20	25,000
Noblehurst Farms	3	Plug-flow; twin cells	Cow Power	747,700	2003	1,600	23	30,000
Patterson Farms	5	Complete Mix	RCM Digesters, Inc.	1,500,000	2005	1,000	22	45,000
Ridgeline Farm	4	Complete mix; twin cells	RCM Digesters, Inc.	622,000	2001	600	20	25,000
Sheland Farms	12	Vertical complete mix	Siemens Building Technologies, Inc.	1,200,000	2007	560	17	14,000
SUNY Morrisville	11	Plug-flow; twin cells	Cow Power	936,000	2007	400	25	10,000
Sunny Knoll Farm	7	Plug-flow	RCM Digesters, Inc.	1,000,000	2006	1,400	18	43,000
Sunnyside Farms	15	Plug-flow with biogas recirculation	GHD	4,500,000	2009	3,750	N/A	N/A
Twin Birch Farms	10	Plug-flow	Anaerobics/ Twin Birch Farm	N/A	2003	1,200	20	29,000
TOTAL				**12,146,700**		**13,860**		**310,000**

[1]To be used when referring to Figure 4.

Table 2. Operational AD Specifications (continued)

Farm	Influent	Stall Bedding	Rumensin® Usage	Solid-Liquid Separation	Biogas Use(s)	Carbon Credit Trading
AA Dairy	Manure, SLS liquid	Sawdust	Yes	Yes; compost produced and sold	130 kW Eng-gen set	No
Aurora Ridge Dairy	Manure	Sawdust	Yes		500 kW	No
Corwin Duck Farm	Manure	None	No	Yes; settling tank and double drum screen	Compressed air generation	No
El-Vi Farms	SLS liquid	Separated digested solids	N/A	Yes; solids used for bedding and sold	Biogas-fired boiler	N/A
Emerling Farm	Manure, hog processing waste	Separated digested solids	N/A	Yes; solids used for bedding	230 kW Eng-gen set	No
New Hope View Farm (formerly DDI)	Manure	Sawdust	No	Not currently in use	(1) 70 kW microturbine	No
Noblehurst Farms	Manure, hog processing waste	Separated digested solids	Yes	Yes; solids used for bedding	130 kW Eng-gen set	Yes
Patterson Farms	Manure, cheese whey, onion waste	Separated digested solids	Yes	Yes; solids used for bedding	A 180 kW and a 200 kW Eng-gen set	Yes
Ridgeline Farm	Manure, various food wastes (hog processing waste, ice cream waste, salad dressing, etc.)	Sawdust	Yes	Not currently in use	130 kW Eng-gen set; Biogas-fired boiler	Yes
Sheland Farms	Manure	Separated digested solids	Yes	Yes; solids used for bedding	125 kW Eng-gen set	No
SUNY Morrisville	Manure	Sawdust	N/A	No	50 kW Eng-gen set	No
Sunny Knoll Farm	Manure	Sawdust	Yes	No	230 kW Eng-gen set	No
Sunnyside Farms	Manure	Separated digested solids	N/A	Yes; solids used for bedding	500 kW Eng-gen set	
Twin Birch Farms	Manure	Separated digested solids	Yes	Yes; solids used for bedding and sold	(6) 30 kW microturbines; biogas-fired boiler	Yes
TOTAL					**2,655 kW**	

Basic aspects of AD systems currently under construction or in start-up and those in the planning and/or design state are shown in Tables 3 and 4, respectively. Considering projects that are both in the planned and under-construction status, approximately **25,000 dairy cows** in NY will add 8 megawatts (MW) to the electricity-generating capacity of digesters currently in operation in NY.

Table 3. Under Construction or in Start-up AD Specifications

Farm	Farm ID[1]	Location (Town)	# of Milking Cows	Digester Type	Primary Biogas Use
Boxler Farms	17	Varysburg	2,000	Plug-flow with mixing	500 kW Eng-gen set
Cayuga County Soil Water Conservation District	13	Auburn	1,000	Complete mix	625 kW Eng-gen set
Lamb Farms	18	Oakfield	1,120	Plug-flow with biogas recirculation	450 kW Eng-gen set
Roach Dairy Farm	24	Scipio Center	1,200	Plug-flow	300 kW Eng-gen set
Swiss Valley Farms	19	Warsaw	1,200	Plug-flow with mixing	300 kW Eng-gen set
Wagner Farms	16	Poestenkill	340	Complete mix	100 kW Eng-gen set
Zuber Farms	21	Byron	1,380	Plug-flow	300 kW Eng-gen set
TOTAL			**8,240**		**2,575 kW**

[1]To be used when referring to Figure 4.

Table 4. Planned AD Specifications

Farm	Farm ID[2]	Location (Town)	# of Milking Cows	Digester Type	Primary Biogas Use
Greenwood Dairy Farm	22	Potsdam	1,200	Complete mix	300 kW Eng-gen set
Oakwood Dairy	26	Auburn	1,600	Complete mix	Bio-methane 500 kW Eng-gen set
Phillips Family Farm	23	North Collins	1,200	Complete mix	300 kW Eng-gen set
Sprucehaven Dairy	25	Fleming	1,850	Complete mix	Bio-methane with 500 kW Eng-gen set
Walker Farms	20	Fort Ann	1,100	Complete mix	225 kW Eng-gen set
Farm 1[1]			2,000	Plug-flow with biogas recirculation	400 kW Eng-gen set
Farm 2			900	Complete mix	225 kW Eng-gen set
Farm 3			1,250	Plug-flow with biogas recirculation	315 kW Eng-gen set
Farm 4			720	Complete mix	135 kW Eng-gen set
Farm 5			637	Complete mix	120 kW Eng-gen set
Farm 6			500	Plug-flow	60 kW Eng-gen set
Farm 7			2,100	Complete mix	2,248 kW Eng-gen set
Farm 8			1,440	Complete mix	300 kW Eng-gen set
TOTAL			**16,497**		**5,628 kW**

[1]Unnamed farms 1 to 8 are farms that have applied to NYSERDA for RPS funding but have not yet had their applications approved.
[2]To be used when referring to Figure 4.

The two NY counties with the largest concentrations of existing and planned AD systems are Cayuga and Wyoming Counties, respectively. Enlarged county maps have been provided to show the digester locations, as shown in Figure 4. The Farm ID numbers provided in Tables 1, 3 and 4 can be used to reference specific farms on this map.

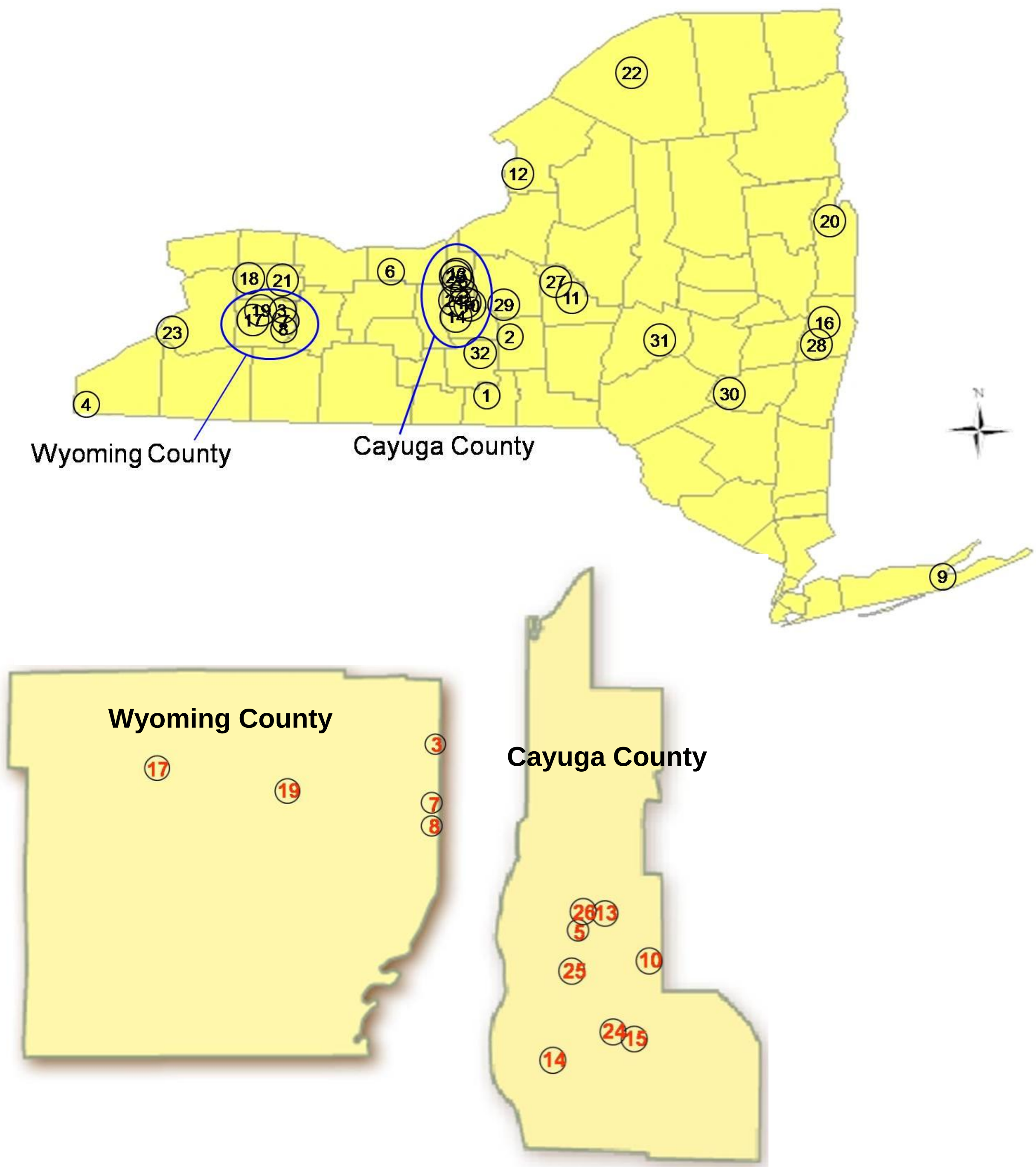

Figure 4. NY and Cayuga and Wyoming County Maps Showing AD Locations by Farm ID Number.

2.3 Summary of Lessons Learned

Most digester owners/operators in NY have reported their positive and negative AD experiences and important lessons learned in different venues. A record has been compiled by the Cornell Manure Management Program and is provided by category in Appendix 6.

Innovation Center for U.S. Dairy combined these common problems, successes and overall lessons learned with research conducted in other parts of the United States along with EPA AgSTAR information, and the results are summarized below.

2.3.1 Economics

The economics of digesters vary widely and depend upon many variables. The consistent issues that arose in NY are:

- Current avoided cost prices paid to producers do not allow for economic viability for the AD system
- Cost estimates for projects have sometimes been unrealistic
- Tipping fees can offset the operational and management costs of the AD
- Lenders view digesters as high lost capital items

2.3.2 Design

Design issues reported by NY dairy producers were numerous. Some design issues were related to site-specific criteria unaccounted for (such as high groundwater tables) and others were a result of shortcomings and/or errors in system design, engineering and/or construction. Issues that were identified by producers included:

- Vetting of digester developers and/or the inclusion of a warranty of work needs to be included in contract to ensure proper design attributes are addressed as determined by the site and climate criteria and considerations.
- The digester must be designed as a complete system and not as an ad hoc integration of components, which has been shown to lead to unanticipated consequences such as structural failures and interconnection issues.
- A process of comparing system designers in a way that provides “apples-to-apples” standards has been suggested to help evaluate the pros and cons of different systems and companies.
- Design components need to incorporate the potential expansion or change in substrate materials according to the possibilities for the producer; alternatively, the producer should be aware of the limitations of a system to ensure the farm doesn’t add inappropriate substrate materials.
- Sizing of the gas handling system needs to account for the additional production of biogas that food waste creates. Pre-planning and analysis of possible food waste sources was helpful to the farm to estimate gas production potential.
- Digesters should be pressure-tested as part of the final inspection procedure.

- Turnkey design was desirable for installation. A complete engine-generator set and biogas handling skid, appropriately sized and assembled in a factory (providing ease of design and mechanical equipment installation) has proven successful in the field. The system was assembled with compatible equipment and controls so on-farm installation was easily accomplished.

- One farm believes that two smaller engine-generator sets should have been chosen instead of one larger unit. Some of the engine-generator set maintenance requires downtime and consequently results in the need to procure power from the local utility, which increases the farm's demand charge.

- Conditioning biogas before sending to the compressors and microturbine is critical for the power generation system. Hydrogen sulfide and water vapor in biogas present the potential for corrosion — the compressor has sensitive components that will corrode.

- Providing a sound insulated engine room can reduce the sound on-farm as well as the sound heard from a distance.

- The heat balance of the digester system is vital. The design needs to address heat recovery from the engine, methods to heat the AD influent, and correct estimates for maintenance heat, which is needed to maintain a constant temperature in all weather conditions.

- Groundwater impingement on the bottom of the digester can significantly reduce the temperature of hot water piped to the digester to maintain operating temperature.

2.3.3 Digestate Management

Digestate management concerns revolved primarily around post-digested separated solids management and nutrient management. They included the following issues:

- Use of post-digested separated manure solids as bedding has proven successful on some farms while not so successful on others.

- Post-digested solids turned into compost are finding marketability in NY.

- Some systems have experienced a decrease in solids as the result of adding additional substrates, which led to the conclusion by a producer that the efficacy of solids digestion is increased with the proper substrate additive.

- Accepting food wastes can be highly profitable if there is the ability to manage the associated imported nutrients as required by the farms' CAFO permits.

- Where land application is restricted due to weather conditions or nutrient restrictions, a viable long-term storage capability must be incorporated into project management needs.

2.3.4 Management Issues for Consideration

Producers provided a variety of comments regarding the management and day-to-day operations of the AD systems. They are provided here as a means of expanding understanding on issues that need to be addressed from an operational management standpoint:

- A Flow gutter often becomes clogged with solids, and must be flushed with milking center wash water. The problem is acquiring clean water to flush with, since the wash water from the foot baths contains copper sulfate, which the farm believes decreases microbial activity in the digester.

- The plug-flow digester on our farm relies on the proper moisture content of the influent; changing the feedstock of the digester too quickly can disrupt the normal functioning of the bacteria and shock the system.

- When a reduced volume of material is transferred to the digester, the amount of heat to the digester is adjusted, since heat will not be needed for incoming manure. Without adjustment, higher temperatures than desired may result.

- There is a significant amount of heat recovered from the engine-generator set, which is used to heat the digester influent, to maintain the digester operating temperature, and to heat the calf barn and milking parlor. Despite the many uses for waste heat in our system, a radiator to dissipate extra heat is still needed. The un-insulated gas utilization building is kept very warm, even in the winter months, due to the excess heat produced by the engine. This offers a prime opportunity for a shop facility.

- Maintaining control of digester operating temperature is important, especially during cold weather. Frozen manure and manure with excessive water regularly bypasses the digester. When the digester feed is reduced, biogas production decreases and less heat is available to warm influent. In this case, either external energy is needed to maintain the digester operating temperature, or the digester needs several months of warmer weather to recover.

2.3.5 Additional Concerns

- Technical service support was found to be lacking for much of the equipment associated with the digester system, including the engine-generator set and electrical connections.

- The AD project required a dedicated person to research the funding opportunities, construction specifics and permitting requirements prior to construction.

- AD systems have associated safety requirements that are new to a production farm that have taken time and investigation to fully understand.

- Currently there are no entities that provide complete technical support or services for AD systems. There are several separate digester components designed by different companies that need to come together for successful digester operation and biogas utilization.

Chapter 2 Reference:

Wright, P.E. 2001. Overview of Anaerobic Digestion Systems for Dairy Farms. *Proceedings of Dairy Manure Systems, Equipment and Technology Conference*; Rochester, NY, March 20-22. NRAES-143. Natural Resource, Agriculture and Engineering Service. Cornell University, Ithaca, New York.

U.S. EPA. 2009. *The AgSTAR Program.* Web site: http://www.epa.gov/agstar/

CHAPTER 3: COSTS, BENEFITS AND FEASIBILITY

1. Several benefits are attributed to the anaerobic digestion of dairy manure, including:
   - Reduction of manure-related odors
   - Reduction of manure-related GHG emissions
   - Improvement in crop utilization of nutrients and therefore a decrease in negative water quality impacts
   - Generation of renewable energy

2. One challenge of performing a comprehensive economic analysis, is that several benefits attributed to anaerobic digestion are difficult to assign a monetary value.

3. NYSEP conservatively states that total biogas production potential is 8 TBtu/year — this translates to 702,000 MWh annually.

3.1 Costs

Discussions with dairy producers have shown that the current capital cost range for complete AD systems is $1,000 to $1,400 per cow equivalent with the engine-generator set component costing about $1,000 per kW of capacity. Commodities of scale are prevalent in these systems. This capital cost range is not all that different from the cost per cow to construct a new dairy freestall barn.

As stated other places within this document, one of the major problems identified by the New York dairy producer is the large capital cost associated with implementing an AD system. Another cost-related problem is the high lost capital of ADs, making it difficult for some farms to secure bank financing.

Other costs that need to be considered are the annual operations and maintenance costs. As an example of this, the estimated cost to maintain an engine-generator set is $0.015 to $0.02/kWh (Martin, 2009). Labor, significant at times, is needed to manage and troubleshoot problems associated with the digester system.

3.2 Benefits

The specific benefits of an on-farm AD system of dairy manure include:

1. Reduction of manure gas odor. Less odor allows a farmer to be more flexible regarding how manure is stored and recycled to the land base.

2. Reduction of GHG emissions. This is good for the environment and further shows consumers that farmers strive to be good environmental stewards.

3. Conservation of nutrients. AD does not consume the manure nutrients of nitrogen, phosphorus or potassium, which are important for crop production. However, at this time, dairy farms generally have more manure nutrients than needed and thus some farms would like to see a digester consume nutrients.

4. Improvement in crop utilization of manure nutrients. Effluent from digesters can be stored long-term without significant odor problems, allowing farmers to apply nutrients to even sensitive field crops in a timely, agronomic fashion.

5. Improvement of water quality. Agronomically preferred application time coincides with periods when predicted runoff and leaching is minimal, thus minimizing contamination to receiving water bodies.

6. Generation of renewable energy. Biogas can be used to generate electricity, heat water, dry materials, or a number of other potential alternative uses that can be used on- or off-farm.

7. Revenue potential. Besides reducing on-farm purchased energy costs for electricity and/or heat, the digester can facilitate other enterprises, such as digested manure solids sale as compost or bedding, excess electricity sales, or co-digestion of food waste for a tipping fee.

8. Pathogen reduction. Cornell research has shown a 99.9% reduction of indicator organisms (those that are commonly used to evaluate the success of a system's performance relative to killing other pathogens). Johne's disease, a disease found in today's dairy cows, is reduced 99% by digestion.

3.3 Feasibility: Economic

In order for an AD system to be a good investment by the dairy producer, the annual cost to own and operate the system must be less than the revenue provided by the system. Potential revenues can come from the sale of:

- Excess electrical energy
- Excess combustion heat
- Carbon credits
- Renewable energy credits
- Post-digested separated manure solids
- Organic fertilizer

Indirect revenue (cost savings) can be obtained by reducing purchased electricity and heating fuels.

3.4 Feasibility: Future AD growth potential and energy outputs

The NYSEP estimates that New York's farms have the potential to produce 6 TBtu of energy from AD systems annually. Based on an average biogas yield of 80 ft^3/cow-day from digesters fed manure only, our calculation shows this represents the digestion of 354,000 milking cows, only about half the population of milking cows in the state. Our analysis of this potential of 6 TBtu/yr shows that 528,000 MWh of electricity could be generated annually.

In addition to farm-based biomass used for biogas production, New York's 128 active food and beverage manufacturing facilities have an estimated biogas-producing potential of 3.9 billion cubic feet per year, or approximately 2.1 TBtu per year. Therefore, the NYSEP states that a conservative estimate for New York's total biogas production potential is approximately 8 TBtu, Our analysis shows this potential translates to 702,000 MWh annually.

If a number of things came together, the longer-term daily potential for biogas production from manure and organic substrates in NY is shown in Figure 5. The analysis calculates the available mass of dairy manure from a total of 453,000 milking cow equivalents (total manure from 80% NY 150 large and 450 medium CAFO farms) co-digested with organic food waste. Energy production due to the co-digestion process is estimated to be three times that of digesting manure alone. The resulting biogas can be transformed into multiple energy outputs as shown. Effluent can be recycled to the land base as fertilizer and biogas can be used to generate electricity, heat, or scrubbed and injected into a pipeline.

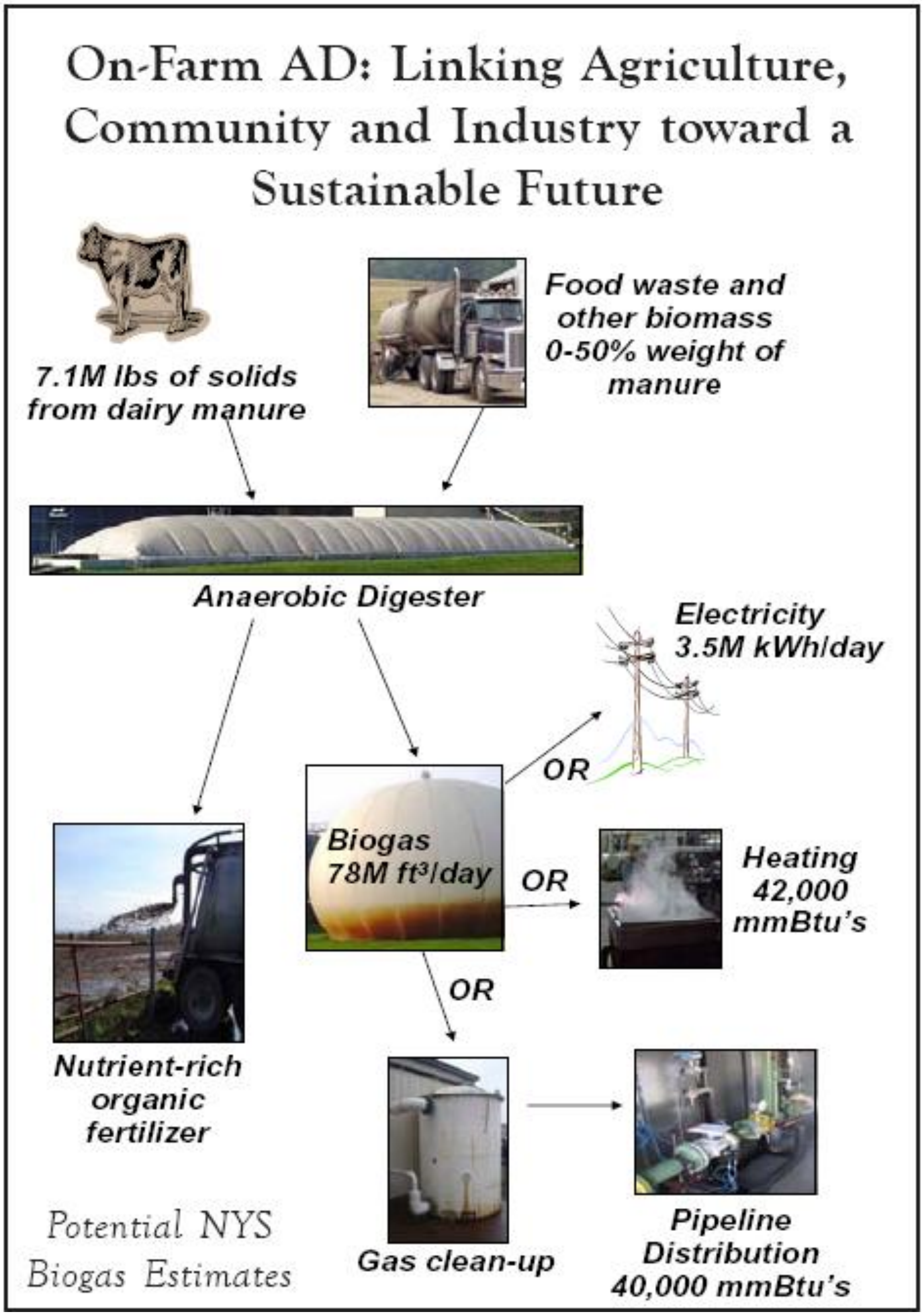

Figure 5. NY biogas potentials (Gooch and Pronto, 2009)

Chapter 3 References:

Gooch, C.A. and J.L. Pronto. 2009. *Biogas News*. Addition No. 3. Cornell University, Ithaca, NY.

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CHAPTER 4: CHALLENGES AND REGULATIONS

1. The Cornell performed survey to determine producer's perspective of barriers to digester development can be summarized by these overall producer-defined barriers:
   - High capital costs
   - Interconnection process and requirements

   Producers currently with and without a digester perceive the process of installing a digester to be difficult.

2. New York provides the opportunity for farms to sell excess electrical power to the utility through the net metering law. Limitations of the current Net Metering law include:
   - Allowable engine-generator set capacity limit of 500 kW
   - Net metering limited to one meter's service load per farm (many NYS farms have multiple service meters)
   - Options limited for net metering involving 3rd party ownership of AD system
   - Co-digestion potential of off-farm biomass weight limited to 50% of digester influent

3. A complaint has been filed to the PSC in relation to current disagreements of interconnection costs incurred by the utility companies in NY.

4. New York has a permitting system in place to provide dairy farmers the opportunity to legally import off-farm substrates for co-digestion. The limiting factor for importation of off-farm substrates for most NY dairy farms is properly balancing the additional imported nutrients as required by their CAFO permit. Suitable advanced manure treatment technologies to condense and remove excessive nutrients from the digester effluent stream are needed, and valid capital and operational data from farm-based installation scenarios is required so the incremental coast of the equipment can be determined.

4.1 Surveys of Producer Perspectives

Two separate surveys were developed in order to gauge producers' perspectives and to present associated barriers to digester adoption in this paper. One survey targeted current digester owners/operators and one survey targeted producers who do not currently own/operate a digester. The surveys were distributed to select farms in August 2009. Individual survey responses to each question asked are presented in Appendix 7, and a summary of all barriers cited by both survey groups is presented below.

Survey #1: AD Operator Survey

This survey was sent to 13 current digester operators, and 12 respondents completed the survey. Two of the respondents were from the same farm and represented the same digester system. Not every question was completed by each respondent. The responses to each question are provided in Appendix 7. In question one of the survey, all responses were higher than a difficulty level of 5, indicating that all producers had more difficulty with the digester system project than anticipated, and the majority of respondents ranked their experience as a Level 8 difficulty. When asked to specify the problems encountered, the majority of respondents cited issues with (in order of popularity):

- Interconnection (nine occurrences)
- Design (seven occurrences)
- Construction (six occurrences)
- Regulations (five occurrences)

The most common response to the question asking for a recommended method to overcome the problems encountered was “to have a complete design, drawings and specifications.” Finally, most producers (nine out of 10) perceived other producers to have a difficult time implementing a digester system.

Survey #2: Producers Without On-Farm AD System Survey

This survey was sent to 85 Northeast Dairy Producers Association (NEDPA) member producers, and 20 respondents returned completed surveys. Their responses to each question are provided in Appendix 7. The majority of respondents have considered or are considering installing a digester on their farm, with most people indicating they seriously considered installing a digester from 2007-2008, and/or in the near future (within five years). The most popular reason cited for *not* installing a digester was capital cost, followed by the belief that it was a poor investment and the third popular reason was that the farm currently uses sand bedding. The majority of respondents believe that other producers have a difficult time installing a digester, and the reasons most cited were (1) high capital cost and (2) operational complexity and additional management needed. When asked to choose from a list of options for barriers to installing a digester, “high capital costs” received the highest response rate, with 19 people perceiving that this is the most serious barrier to further digester development in NY. The second most chosen barrier was “the perceived shortcomings of existing systems.” And finally, when asked (unprompted) to identify the most serious issue that needs to be overcome in order to expand digester installations in NY, the reason was high capital costs.

A summary of all barriers mentioned by respondents from the first survey (currently operating an AD) is shown in Figure 6. The summary of barriers mentioned in the second survey (not currently operating an AD) is shown in Figure 7.

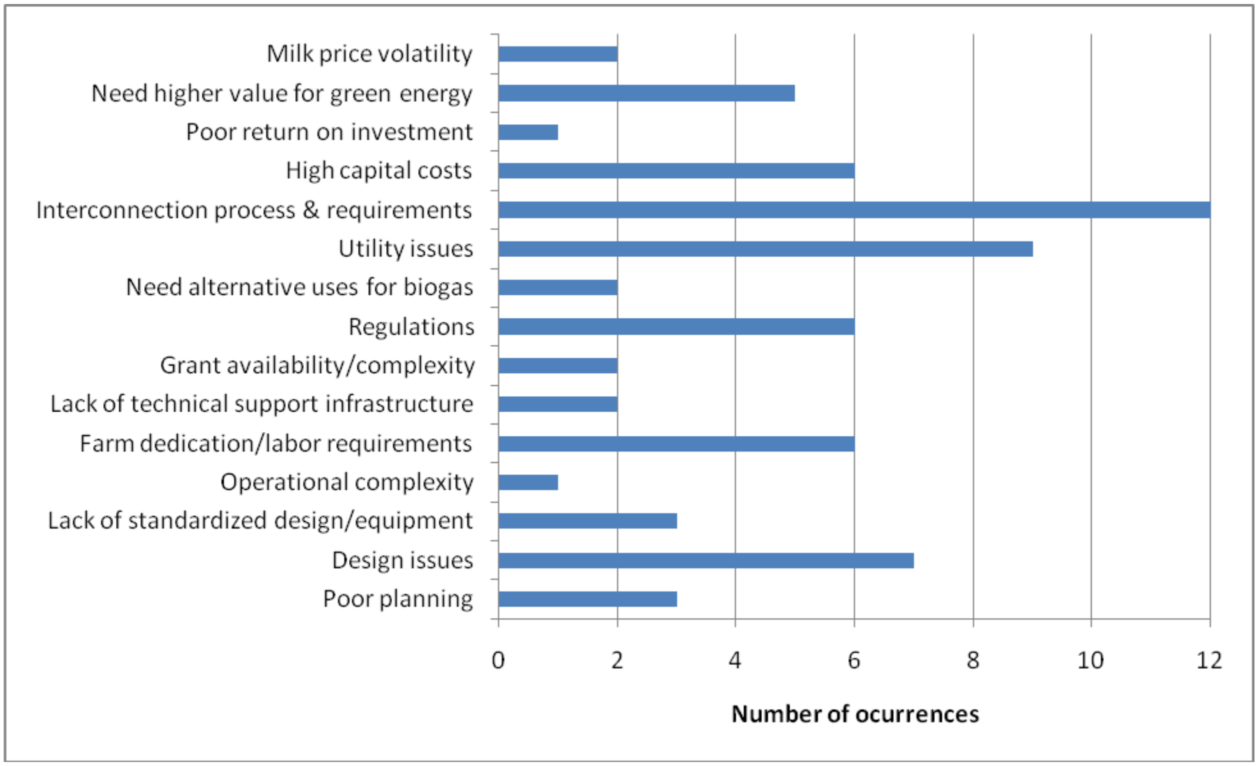

Figure 6. The occurrences of each barrier cited in Survey #1 (AD operators)

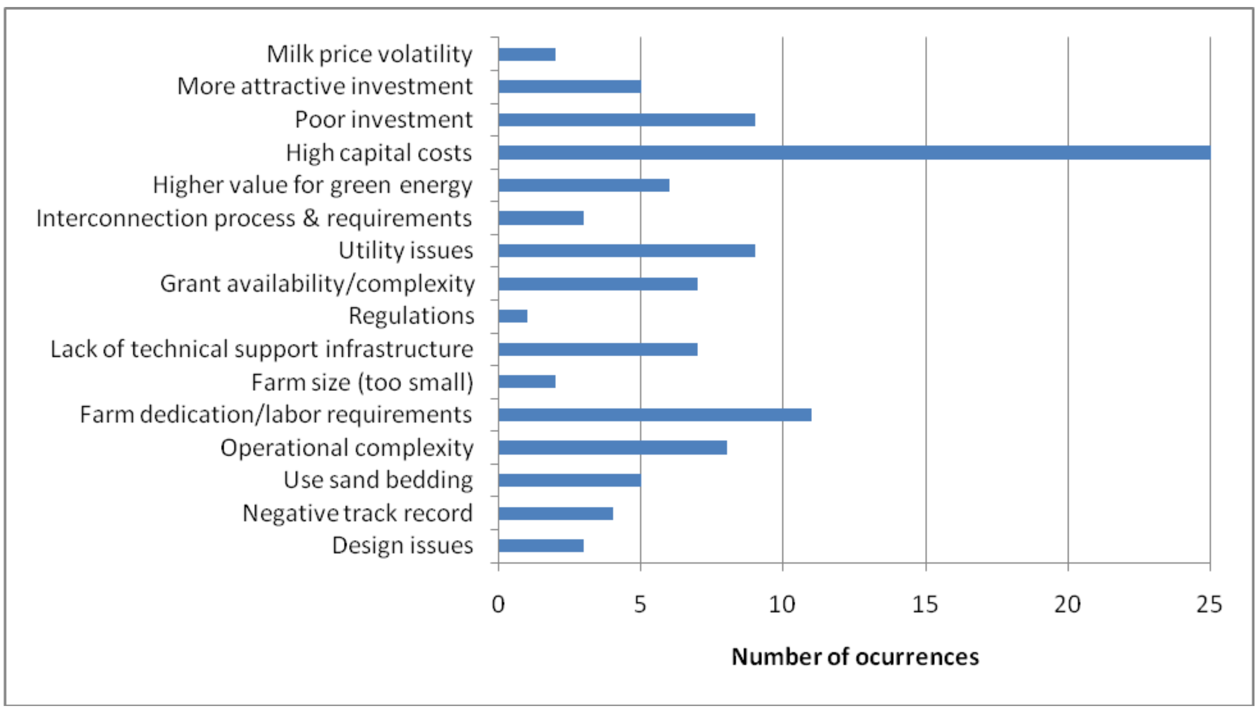

Figure 7. The occurrences of each barrier cited in Survey #2 (Farms without ADs)

It is a common response from producers with and without digesters operating on-farm, that utility interconnection is believed to be one of the most arduous tasks of installing a digester. The main issue, as understood through interactions with the utilities, is a simple one — farms are located in rural areas usually at the end of distribution lines where the electric grid ends in a series of small feeder lines. The lines are not designed or able to handle the large amounts of power farm AD generators wish to put back on the grid (NYSEG, 2009). In order for digesters to realize positive economics, several issues with electricity buy-back need to be addressed (Jones, 2008). To achieve the potential benefits of widespread AD, challenges seen by the dairy producers need to be addressed, regulatory issues need to be resolved, and opportunities enhanced and applied.

As demonstrated by the results of the two surveys conducted by Cornell, and echoed in an independently conducted survey (see Appendix 8), the high capital cost of digester systems is the major challenge to be addressed. Some of the specific aspects of the cost issue are summarized below:

1. High capital cost. High initial costs make investing in an AD prohibitive by all but the most profitable farms, unless significant amounts of outside grant dollars are secured.

2. High lost capital. Digesters are viewed as high lost capital items, as much as 90%, resulting in difficulty securing loans or obtaining subsequent loans for other dairy facility capital projects.

3. Lack of predictable return on investment. High capital costs can be overcome if competitive returns on investment can be realized; however, there is a lack of outstanding examples of this in NY.

The surveys also confirm some of the lessons learned, provided in detail in Appendix 6, with respect to the need for qualified and trained personnel for design and operation of digester systems. A limited pool of designers with qualified credentials currently exists. However, with the recent surge in producer interest, more technical support is becoming available to perform design and maintenance work. A designated farm employee must be trained in the principles and management of the digester system in order to ensure its success. With greater attention to expanding green jobs, opportunities for training may become available.

4.2 Net Metering Law: Benefits, Limitations and Challenges

The original NY Net Metering law was signed into law on Aug. 13, 1997 (New Rules Project, undated). The current Net Metering law is outlined in Sections 66-j and 66-l of Article 4 of the Public Service Law (New York Consolidated Law Service, 2008), and includes net energy metering for farm waste systems. Net energy meter means a meter that measures bi-directional flow of electricity between the electricity supplied by an electric corporation to a customer-generator and the electricity provided to the corporation by that same customer-generator. Farms can elect to deliver excess electrical power to the grid through the existing net metering program, or by alternative tariff provisions for selling power.

For farm waste customer-generators that qualify for net metering under current statutes, the current NY Net Metering law mandates that:

- Biogas-derived electricity sold back to the grid be generated at a maximum capacity of 500 kW.

- If the generating capacity (kW) of the farm waste generating system surpasses 20% of the capacity of the local feeder line, the utility may require additional compliance to meet applicable safety standards for other customers on the line.

- Electricity sold back to the grid be fueled by a minimum of 90% annually by biogas produced from the AD of agricultural waste.

- Biogas used to generate electricity sold back to the grid be produced from the AD of at least 50% livestock manure by weight.

- The customer-generator pay the electric company's costs to install a transformer or other equipment to provide for the safety of the line, up to $5,000 for a farm waste generator; the utility shall not impose any other fees for interconnecting to net meter a system.

- Net metering systems are limited to a customer of an electric corporation, who owns or operates farm waste electric generating equipment located and used at his or her "farm operation."

The Net Metering law also contains requirements for utility companies with regards to purchasing electricity from customer-generators. The electric utility company will provide for the interconnection of farm waste electric generation equipment, if that customer-generator enters into a net metering contract with the utility. The utility company must also "establish consistent and reasonable rates" for net metering customers, and must provide the net metering program until 1% of that utility's 2005 demand is reached by the generating capacity of farm digester and photovoltaic solar power generators in their system. On Jan. 1 2012, the PSC can increase the 1% limit on the overall program capacity limit if net metering is determined to be successful. Each utility must establish standards for net metering and farm waste generating system interconnection. Part of these standards incorporate Standardized Interconnection Requirements (SIR); see Appendix 11 for more detail. This requirement is met by the utility developing a tariff approved by the PSC. The PSC can determine whether these standards for interconnection are reasonable.

Net metering billing is determined using the following criteria:

- If the amount of electricity supplied by the utility is higher than that provided by the customer-generator to the utility during the billing period, the utility will bill them for the net electricity supplied at the same rate per kWh as other customers in the same service class that do not generate electricity on-site.

- If the amount of electricity provided by the customer-generator to the utility is more than the amount of electricity provided by the utility to the customer-generator during the billing period, the utility will apply a credit to the customer-generator's next bill for the net electricity provided, at the same rate per kWh as other customers in the same service class which do not generate electricity on-site.

- On an annual basis, the utility will pay the customer-generator for the value of any remaining credit for the excess electricity produced by the customer-generator and the rate will be the utility's avoided cost to the customer-generator.

- If the utility imposes charges based on kW demand for customers in the same service class as the customer-generator, but which do not generate electricity on-site, the utility may impose the same charges at the same rates as for the customer-generator, but the kW demand must be determined by the maximum measured kW demand actually supplied by the utility to the customer-generator during that billing period.

Based on currently available data, our calculations show that, of the 1% net metering program limit for the three major utilities — National Grid, NYSEG and RG&E — 13%, 35% and 4%, respectively, is currently occupied, as shown in Table 5. Each of these three utilities' tariffs contains the clause that the net metering program for solar (in the table referred to as PV) and farm waste (in the table referred to as AD) generators is available until the threshold of 1% of that utility's demand for the year 2005, is reached. More than half this capacity remains available for the three utility companies serving areas most likely to support on-farm ADs. Whether this 1% limitation will keep some future digester systems from the benefits of net metering or not will depend on several factors, such as the rate of installation of PV systems and digester systems and their locations. It appears that a larger percentage of the NYSEG service territory is occupied as compared with National Grid's.

Table 5. Status of 1% of 2005 Electric Demand Net Metering Limit

Utility	PV kWs occupied	AD kWs occupied	1% of 2005 demand (kW)	Portion of 1% already occupied by solar and farm waste generation, combined	Portion of 1% free
National Grid	6,375	2,180	65,360	13%	87%
New York State Electric and Gas	4,770	4,995	28,260	35%	65%
Rochester Gas & Electric	609	0	16,250	4%	96%

4.3 Current Challenges Regarding Utility Interconnection Costs

Currently, there are issues with several digester installation projects regarding utility interconnection costs. The basic issue is the lack of definitive interpretation of interconnect costs by PSC to address a difference in opinion between the utility companies and customer-generators that limits interconnect costs to the $5,000 cap limit stated in the Net Metering law for a dedicated transformer or transformers, or other equipment to protect the safety and adequacy of electric service provided to other customers. Utility companies have quoted significant interconnection costs to some farm waste-to-energy generation systems for reasons that include safety of the grid network. Parties responsible for planning and installing the farm waste-to-energy generation systems have not been anticipating the potentiality of large interconnect during project planning. In a number of projects, this can tip the economics in an unfavorable direction and create concerns over the economic and overall feasibility of most farm-waste generation systems.

- One farm-waste generation project currently under construction has recently filed a complaint with the PSC (Lutz, 2009) regarding the interconnection costs they were quoted by the utility company National Grid. Boxler Dairy Farms was quoted more than $416,000 by National Grid for system upgrades to be able to interconnect their 500 kW generator fueled by AD biogas (National Grid, 2009).

4.4 NY Regulations Affecting Farm Importation of Off-Farm Biomass

Dairy farms are well positioned to be significant contributors to the state's renewable energy goals and beyond. There are significant opportunities for dairy farms to co-digest off-farm biomasses, commonly referred to as substrates, with dairy manure and other farm-generated biomasses.

Co-digestion provides the opportunity to significantly increase biogas production per unit volume of influent over that of manure-only-based systems. A few dairy farms in NY have been co-digesting at their sites for several years and monitoring analysis shows biogas production on these farms is **three times** that of other monitored farms with manure only systems (Gooch et al., 2007). Even greater production is possible with co-digestion of specifically selected substrates. A Wisconsin farm-based digester produces five times the biogas due to co-digestion. Biogas production is increased in two ways, by:

1. Conversion of the additional biochemical energy contained in the substrate itself

2. A symbiotic effect that results in more efficient utilization of the biochemical energy contained in manure

An increased number of partnerships between dairy farms and food processors, waste haulers and communities (both private and public entities) are needed to significantly bolster the number of digesters in the state and subsequent biogas production.

There are three NY regulations under two different NY agencies that govern farm importation of off-farm biomass. They are the farm's CAFO permit, a food waste importation permit and the Net Metering law. The CAFO and food waste permits are administrated by NYSDEC and the Net Metering law by the PSC. An overview of each is provided below.

4.4.1 CAFO Permit

Almost all dairy farms with 200 to 699 cows are required to have a medium CAFO permit while those with 700 or more cows are required to have a large CAFO permit. Currently, there are about 450 medium-permitted dairy CAFOs and 145 large-permitted dairy CAFOs in New York (NYSDEC, 2009).

While the CAFO permit itself does not specifically address farm importation of off-farm substrates for co-digestion, it does specifically require the farm have a Comprehensive Nutrient management Plan (CNMP). The CNMP is essentially a tool to account for all of the nutrients coming on the farm and leaving the farm, and the CAFO permit stipulates that there needs to be a balance between inflows and outflows of the nutrients N, P and K. The procedure for doing this is called a "Whole-Farm Nutrient Mass Balance." The CAFO permit requires each farm to have a third-party planner certified by the state to develop each farm's CNMP.

It is likely that the most difficulty farms will have with importing substrates for ADs is difficulty in maintaining mass nutrient balance. Substrates contain nutrients N, P and K and therefore add to the nutrients coming on-farm. The concentration, generally expressed at the farm level in units of lbs/1,000 gallons varies by substrate. The NY farm with the longest history of importing food waste for co-digestion in the U.S. has sourced substrates from multiple sources since 2004. Digester substrate sampling from January 2004 to May 2005 showed that overall a tanker-load of imported food waste had the same nutrient content of a tanker load of that farm's dairy manure (Gooch and Inglis, 2007).

Farms that are best positioned to import substrates for co-digestion are those that have access to cropland that exceeds that need for forage crop production for their herd. Since this is generally not the case in NY, wide-span adoption of co-digestion systems hinges on the economics associated with not only producing and utilizing the biogas but also with the equipment needed to condense excessive nutrients in digester effluent so they can be exported. Overall, the best substrates for co-digestion in many cases are those that produce the highest-value biogas (a combination of quantity and quality) with the lowest associated nutrient loading. This can be expressed as mmBtu/lbs N, P and K.

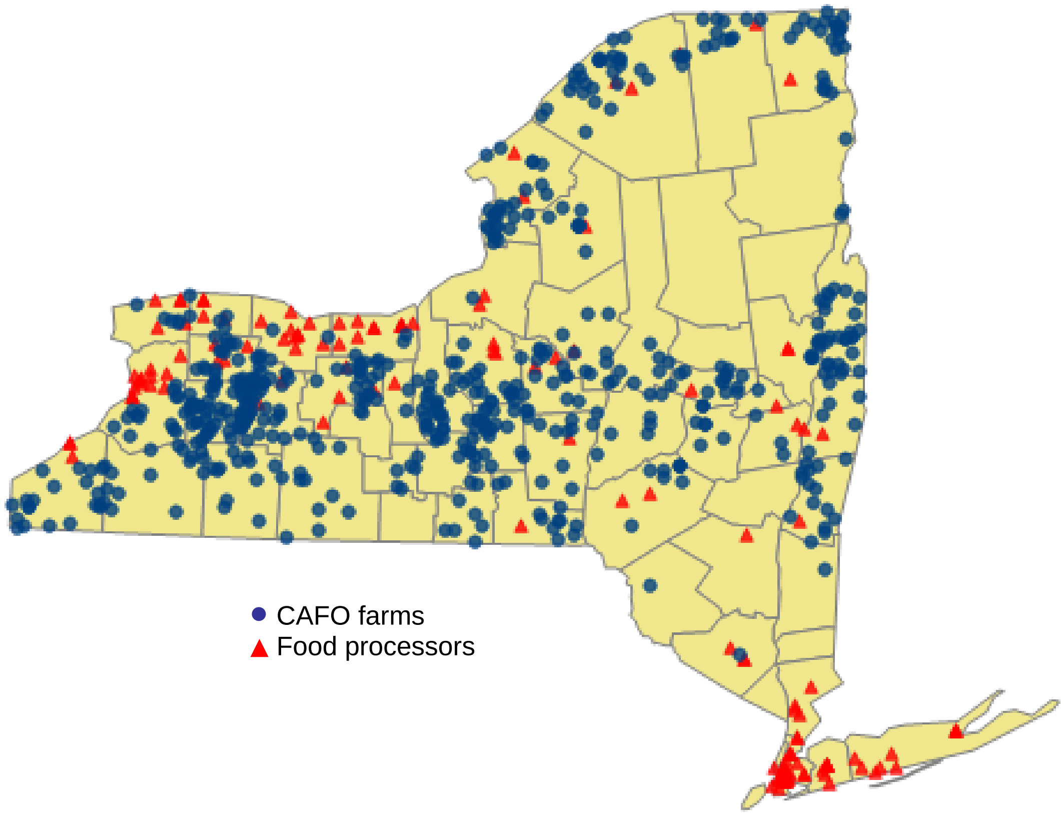

Figure 8. NY Map of CAFO Farms and Food Processing Locations (www.wastetoenergy.bee.cornell.edu)

4.4.2 Food Waste Permit

Unlike some of the other states, NY has an existing permitting process for farms to receive and land-apply food waste, food processing waste, or other organic waste on agricultural land. As a result, a number of NY farms have been paid a tipping fee to receive whey and other food processing byproducts and directly land-apply them for many years. The farm incurs costs to temporarily store and then to land-apply the food waste. Co-digesting food waste has the potential to provide increased incremental value. The location of various food processors in relation to CAFO farms is shown in Figure 8.

There are three permits available from NYSDEC for farm importation of biomass wastes. They are an exemption permit, registration permit, and a permitted site. The appropriate permit depends primarily on the type of waste but sometimes also on the quantity. An overview of each is provided below:

4.4.3 Exemption Permit

The exemption permit is the lowest-level permit and is issued when there is a low potential for environmental harm from the imported biomass. Biomass must be visually *recognizable*. Examples are the following vegetable residues: corn husks and cobs; cabbage leaves; grapes and apple pumice; bean snips; and carrot, tomato and potato skins.

4.4.4 Registration Permit

The registration permit, similar to the exemption permit, is based on the determination there is limited potential for environmental harm from the imported biomass. However, this permit covers the case when the biomass is visually *non-recognizable*. Examples include: milk processing byproducts such as cheese whey, whey permeate and lactose; brewery and winery wastes; and byproducts from canned, frozen or preserved fruit. The permit recognizes that biomasses imported under this permit are those generally in a liquid form, and it sets a limit on the importation amount of 10% of the manure storage volume.

The permit requires specific requirements above that of the exemption permit. The biomass needs to be analyzed for its composition, and sets limits when the biomass can be land-applied based on field and weather conditions.

4.4.5 Permitted Site

A permitted site permit is needed for facilities importing biomass that require greater DEC review and oversight or when the exempt or registered facilities are out of compliance. This is the highest-level permit of the three-tiered permit system and has the most onerous requirements. A vicinity map and information about flood plains, wetlands and soil types need to be developed and maintained. Detailed operation records tracking the rates and methods of material application and incorporation along with hydraulic loading rates need to be maintained and kept current. Additionally, specific written permission is required from landowners of land were the food waste is land-applied if it is not owned by the permit holder. Chain-of-custody forms need to be kept for all biomasses imported under this permit.

4.4.6 Net Metering Law

The Net Metering law also has stipulations on the amount of imported biomass that can be co-digested. Specifically, a farm is limited to importing 50% of its total digester influent weight in the form of off-farm substrates. At this time, this is not a limiting factor of farm importation of substrates.

Chapter 4 References:

Gooch, C.A., S.F. Inglis, and P.E. Wright. 2007. Biogas Distributed Generation Systems Evaluation and Technology Transfer Project – Interim Report. Prepared for: The New York State Energy Research and Development Authority. Albany, NY. April 15, 2007.

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New Rules Project. Undated. Net metering from other states. Web address accessed 2009: http://www.newrules.org/energy/rules/net-metering/net-metering-selections-other-states

New York Consolidated Law Service, Public Service Law. 2008. Article 4. Provisions Relating To Gas And Electrical Corporations; Regulation Of Price Of Gas And Electricity. NY CLS Pub Ser § 66-j and § 66-l Web address: http://www.dsireusa.org/documents/Incentives/NY05R1.htm

NYSEG 2009 Personal communication.

CHAPTER 5: NY ENERGY OPPORTUNITIES

1. NY has been a leader in setting goals and providing financial incentives for renewable energy. This has made funding support available for expanded digester use in the state.

2. The current NY renewable energy goal, '45 x 15' is comprised of 30% of electricity demands coming from new renewable energy projects, and 15% electricity demand reduction through energy efficiency measures both met by 2015.

3. NYSEP estimates farms have the potential to produce 6×10^{12} Btu of energy per year, or an equivalent of 528,000 MWh/year of electricity. Our estimates show a potential of 1,275,000 MWh/year when statewide available manure is co-digested with various substrates also available statewide.

4. RECs can provide an additional revenue stream for digester projects.

5. The RPS program is administered by NYSERDA, as designated by the PSC.

6. RGGI is a collaboration of 10 northeastern and mid-Atlantic states that have formed the nation's first mandatory cap and trade market-based effort to reduce GHG emissions.

7. GHG emissions from dairy farms can be reduced by the inclusion of an AD that captures and combusts methane from manure.

8. There are several methodologies to quantify GHG emission reductions, and subsequently several markets with varying credit prices to trade emission reduction credits.

5.1 Energy Policies and Plans Supporting Biogas Energy Production

In 2003, then New York Governor George Pataki proposed that 25% of electricity demand in NY be supplied by renewable sources by 2013 (Urbina, 2004). In 2004, the Public Service Commission (PSC) adopted Governor Pataki's plan, saying 3,700 MW of new renewable energy capacity would be installed by 2013 from wind, solar, biomass, wave sources, fuel cells and hydro upgrades (*Environmental Building News*, 2004).

More recently, the New York State Energy Plan (www.nysenergyplan.com/stateenergyplan) was released in draft form (2009), including several assessments, issue briefs and recommendations pertaining to specific topics surrounding the issue of renewable energy. The New York State Energy Plan (NYSEP) was prepared and issued by the NYS Energy Planning Board, chaired by the governor's office and including members from seven state agencies, including the Department of Environmental Conservation, Department of Public Service and the NYS Energy Research and Development Authority. The NYSEP draft calls for significant production of energy from ADs based on continued incentives for this and other types of renewable energy.

5.2 NYSEP Review

The following information is summarized from the Renewable Energy Assessment document, which can be found in the 2009 NYSEP. (Two other sections of the NYSEP – the Climate Change Brief and the Energy Infrastructure Brief – which relate to AD, but to a lesser extent, are summarized in Appendix 10).

The first state renewable energy goal, set by Governor Pataki was the ‘25 by 13’ goal: 25% renewable-sourced electricity by 2013. Current New York Governor David Paterson increased this goal when he took office in 2008, to become the ‘45 by 15’ clean energy goal, which challenges the State to meet 45% of electricity demands through increased energy efficiency measures and new renewable energy projects by 2015. This goal is comprised of a 15% reduction of energy use through energy efficiency measures and a 30% increase in the electricity supplied by renewable energy sources (*Environmental Building News*, 2004).

5.2.1 NYSEP

The NYSEP outlines several benefits that can be attributed to the increase in renewable resources used to generate electricity in NY.

- Decrease in electricity prices: The NYSEP projects the price of electricity in 2018 to be 0.06 to 0.16 cents per kWh lower than it would be without the RPS-driven implementation of renewable energy technologies.

- Environmental benefits: A reduction of fossil fuel-based electricity generation will result in a reduction of air pollutants and GHG.

- Public health improvements: The NYSEP suggests that with an increase of electricity derived from renewable sources, impacts to public health will be reduced, mainly due to the decreased air pollutants and fossil fuel-based emissions.

- Economic development: The NYSEP projects that renewable energy technology expansion will support job creation and economic development opportunities.

- Utility grid improvements: Some renewable energy technologies, including AD systems that generate power and sell it to the utility, have the potential to reduce the occurrence of bottlenecks in the grid.

The NYSEP identifies several barriers to the growth of the renewable energy industry. Those that are applicable to ADs are:

- High capital cost
- Lack of a skilled workforce
- Limited grid infrastructure
- Limits to net-metering

The NYSEP cites “variable energy production” as another barrier, however, an AD is different from other mainstream renewable energy systems in that it is well suited to generate a constant and stable supply of electricity in all seasons and weather patterns.

According to NYSEP, biogas (from several sources, including those other than on-farm AD biogas projects) represented 1.3% of the NY renewable energy generation portfolio as of 2007. Gigawatt hours (GWhs) of electricity generation attributed to engine-generator sets fired with biogas from several sources (landfills, wastewater treatment plants and on-farm AD) are shown in Table 6 on an annual basis from 2001 to 2007.

Table 6. New York Renewable Resources: Electricity Generation (GWh)

Year	Electricity Generation (GWh) from Biogas (methane)
2001	205
2002	276
2003	256
2004	261
2005	264
2006	337
2007	375

The NYSEP estimates that New York's farms have the potential to produce 6 TBtu of energy from AD systems annually. Based on 80 ft^3/cow-day, our calculation shows this represents the digestion of 354,000 milking cows, only about half the population of milking cows in the state. Our analysis of this potential of 6 TBtu/yr shows that 528,000 MWh of electricity could be generated annually.

In addition to farm-based biomass used for biogas production, New York's 128 active food and beverage manufacturing facilities have an estimated biogas producing potential of 3.9 billion cubic feet per year, or approximately 2.1 TBtu per year. Therefore, the NYSEP states that a conservative estimate for New York's total biogas production potential is approximately 8 TBtu. Our analysis shows this potential translates to 702,000 MWh annually.

The NY Department of Environmental Conservation (DEC) is currently analyzing the potential for waste diversion and energy creation from residential organic waste, which, if used in AD systems, would further increase the total biogas-producing potential for the state. With the collection of larger amounts of organics from other sources beyond the food and beverage manufacturers, our analysis shows that as much as 1,275,000 MWh could be produced annually from digesters treating manure and larger quantities of other organic substrates. The feasibility of such production would depend on a number of factors, such as the ability to keep such organic separate from unacceptable materials, biogas potential of these organics, collection and transportation costs, and availability of adequate land to apply the digested materials.

With recognition of the potential energy supply that could be provided by AD biogas and from other renewable in-state energy sources, the NYSEP draft makes several recommendations for actions designed to support the further development of such in-State sources:

- Expand the renewable portfolio standard (RPS) program to meet the governor's goal to meet 30% of the state's electricity needs with renewable resources by 2015, taking into consideration the voluntary market and other renewable energy initiatives of the state's energy authorities and agencies.

- Create a tracking and trading system for renewable energy credits (RECs) to foster development of a robust voluntary market for REC purchase and to help insure the integrity in measuring compliance with the RPS.

- Continue to provide incentives for environmentally beneficial, renewable distributed generation (DG) resources, including combined heat and power (CHP), with specific targets determined by the Public Service Commission (PSC) in the expanded RPS proceeding, funded through the customer-sited tier. (The customer-sited tier of the RPS program has provided funding incentives for AD gas to electricity projects.)

- Examine the transmission system needs to identify and evaluate appropriate investment strategies needed for bulk transmission system upgrades or expansions needed to allow for deliver of the energy output from renewable energy systems.

- Amend the Net Metering law to provide greater flexibility to commercial customers to size systems to meet a greater percentage of their energy requirements, while ensuring that system reliability is not negatively impacted.

- Examine protocols used by the New York Independent System Operator (NYISO) and utilities for connecting DG sources to the grid to help ensure such implementation is timely and cost-effective.

5.2.2 Renewable Energy Credits (RECs)

RECs addressed in the NYSEP draft are one opportunity to monetize the environmental benefits of producing renewable electricity. Since electricity supplied by renewable resources reduces the need for electricity produced from conventional fossil-fueled generators, an REC represents the environmental benefits of this displacement. Selling RECs attributed to a renewable energy project provides a revenue stream for the project and also gets clean power for sale to those who desire to purchase it for a premium price.

In NY, most RECs are purchased through the RPS program for both main and customer-sited tier programs, but they also can be sold on the voluntary market. The RPS program contains a measure that caps bids at 95% of a facility's available RECs so that the remaining 5% is available for voluntary sales. The Department of Public Service (DPS) estimates that since deregulation, more than 60,000 customers have voluntarily purchased green power.

The concept of the RPS policy for NY was first proposed in the 2002 State Energy Plan and further developed and adopted by the PSC. The PSC designated the New York State Energy and Research Development Authority (NYSERDA) to administer the RPS program. NYSERDA is responsible for procuring 71% of the total RPS policy goal, or, 10 million MWh. The RPS program is funded by a surcharge paid by all electric customers in the system benefits charge (SBC) area of NY. The RPS goals have been changed since Governor Paterson increased the state's renewable energy target to '45 by 15'. A current review of the RPS program goals can be found in the RPS Performance Report in Appendix 9.

As noted in the NYSEP draft some of the RECs will be procured outside of the RPS program. Executive Order 111 (EO 111) states that state agencies will supply 1% of the RPS targets by meeting approximately 20% of their energy needs with renewable sources by 2010. NY electric customers are projected to contribute 4% of the RPS targets through participation in voluntary markets that charge a premium for green electricity (NYSEP, 2009).

However, AD projects that generate electricity usually fit in the RPS program under the Customer-sited Tier (CST) electricity generation category, which consists of smaller “behind the meter” electric generation facilities. It is anticipated that these facilities will supply 2% of the resources needed to meet RPS program goals. Other technologies eligible for CST funding have been solar-photovoltaic, small wind turbines and fuel cells. To date the CST has received applications for AD projects totaling some $21.3 million in incentives, which exceeds the total current allocation of $20.1 million.

The RPS program also funds projects under the Main Tier generation category, which consists of larger facilities such as large wind farms, the biomass portion of coal-fired power plants, and re-powered hydropower plants. These types of facilities are expected to supply the majority — 98% — of the resources needed to meet RPS program targets. Larger digester system or aggregated smaller digester power generation projects also could qualify to participate in the Main Tier bidding process. The entire RPS program, both Main- and Customer-Sited Tiers, is now undergoing its scheduled 2009 review. Whether additional funds will be allocated for digester gas-to-electricity projects and the amount of any such allocation will be determined by the PSC after interested parties have commented on the case.

5.2.3 Regional Greenhouse Gas Initiative

The Regional Greenhouse Gas Initiative (RGGI) is the nation’s first mandatory cap and trade, market-based effort to reduce GHG emissions. It is another potential source of funding for digester projects that reduce the quantity of methane that is emitted from the farmstead. The expansion of the RGGI program is expected to make renewable electricity generation more competitive with fossil-fueled generation. RGGI currently only places a cap on CO_2 emissions from large-scale fossil-fuel powered electricity generation facilities (e.g., Cayuga AES plant in Lansing, N.Y.). These facilities can purchase offsets from generators, for example, on-farm AD projects, that generate electricity using non-fossil fuel sources, therefore off-setting the amount of power needed from the fossil-fuel powered generators. RGGI could be a potential revenue stream for AD projects, if certain criteria are met.

5.2.4 Power Purchase Agreements (PPA)

Power purchase agreements (PPA) are contracts between energy providers and utilities or other electricity customers that specify the terms and conditions under which electricity will be generated and purchased, and requires the energy provider to supply electricity at a specified price for the life of the agreement. A PPA is a potential future arrangement that could apply to AD projects, to stimulate further development and new installations.

5.3 Renewable Energy Stance of Major NY Utility Companies

The service territories of the major utility providers in NY are shown in Figure 9. Regulations pertinent to on-farm AD from the most recent utility tariffs are provided in Appendix 12 for NYSEG, RG&E and National Grid.

5.3.1 NYSEG, RG&E

Both NYSEG and RG&E offer customers the ability to purchase renewable energy through their *NewWind* program and charge a premium price to participating customers to support additional wind energy capacity to the grid. Both companies’ Web sites have the following statement on their renewable energy-focused page:

"We conduct our business and facility operations in a manner that minimizes adverse environmental impacts on present and future generations. One of our goals is to reduce the amount of CO_2 released into the atmosphere as a result of generating electricity." - NYSEG

5.3.2 National Grid

National Grid offers a similar program called "*GreenUp*" - a renewable energy program that supports wind, solar, biomass and hydro-generated electricity added to the grid. The company also supports and contributes to the Renewable Energy Trust Fund.

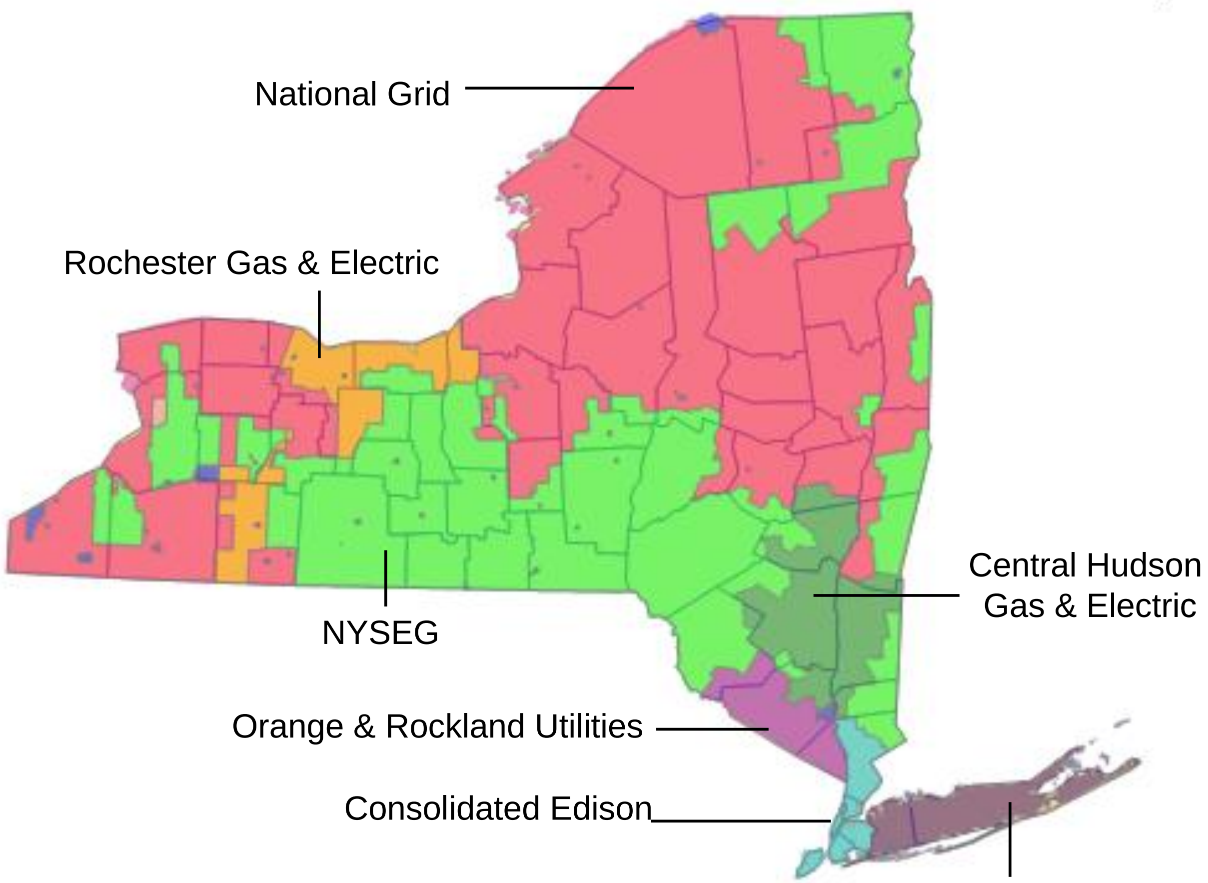

Figure 9. NY Utility Company Territories (www.wastetoenergy.bee.cornell.edu)

5.4 Greenhouse Gases and Anaerobic Digestion

The Innovation Center for U.S. Dairy is currently finalizing one of the most comprehensive evaluations of the GHG footprint for fluid milk in the United States. It assesses the footprint for the entire chain — from farm to disposal of the packaging by the consumer. Estimates suggest the milk production step and associated on-farm practices, are responsible for the largest component of GHG emissions (Innovation Center for U.S. Dairy and Blu Skye, 2008). Utilization of an AD to manage manure on-farm can lead to significant reductions in the emission of GHG from the milk production level (U.S. EPA, 2008).

All GHG offsets are put on an equivalent basis of 1 metric tonne of carbon dioxide equivalents (CO_2e), and the labeled units to denote this are "TCO_2e." A CO_2 equivalent puts other GHG on an equivalent basis with CO_2 since other gases, like CH_4, are more potent in terms of their effect on the atmosphere (Carbon Zero, 2009). “The concept of a global warming potential (GWP) was developed to compare the ability of each GHG to trap heat in the atmosphere relative to another gas. The definition of a GWP for a particular GHG is the ratio of heat trapped by one unit mass of the GHG to that of one unit mass of CO_2 over a specified time period” (U.S. EPA, 2006).

The carbon trading market is in its infancy in the United States, as compared with other countries around the world. The most notable carbon trading markets currently in existence in North America are: Chicago Climate Exchange (CCX), Regional Greenhouse Gas Initiative (RGGI) and the California Climate Action Registry (CCAR). Each of these markets has its own methodology for calculating emission reductions. The U.S. EPA also has a methodology titled “*Climate Leaders Greenhouse Gas Inventory Protocol Offset Project Methodology*” specifically developed to calculate reductions for projects “managing manure with biogas recovery systems” (U.S. EPA, 2008). This methodology was developed in order to serve as a standard for the industry, but has not yet proved to gain widespread use (Penque and Belcher, 2009). The following is a review of the major carbon trading markets now operating in North America.

5.4.1 Climate Leaders

Although the EPA Climate Leaders methodology is not yet widely used to verify GHG emission reductions, some industry leaders believe this may become the standard method for calculating reductions, as the U.S. transitions into a national cap and trade system (Penque and Belcher, 2009). This methodology calculates emission reductions by taking the difference between the baseline emissions and the project-related emissions, and also takes into account the potential leakage from the project. “The emission baseline for a manure management methane collection and combustion project is the manure management system in place prior to the project” (U.S. EPA, 2008). Project-related emissions are emissions that have occurred after the project has been completed and the operation has been monitored. Leakage is defined as an increase in GHG emissions or decrease in sequestration caused by the project but not accounted for within the project boundary (U.S. EPA, 2008). The EPA Climate Leaders methodology uses a factor of 21 for the GWP of CH_4. Lastly, the Climate Leaders methodology may yield comparatively low emission reductions for projects in cold climates, due to the procedure used to calculate volatile solids (VS) degradation in the baseline scenario.

5.4.2 RGGI

RGGI has not been widely adopted as a methodology to verify emission reductions, mainly because of the initially low prices per metric tonne of CO_2e developed by the market. RGGI calculates emission reductions simply by determining the baseline CH_4 emissions and then subtracting any transportation-related emissions for conveyance of manure or other organic waste from off-site for inclusion to the AD. The methodology states, “The emissions baseline shall represent the potential emissions of the methane that would have been produced in a baseline scenario under uncontrolled anaerobic storage conditions and released directly to the atmosphere in the absence of the offset project” (RGGI model rule, 2007). The RGGI methodology uses a factor of 23 for the GWP of CH_4.

5.4.3 CCAR

CCAR is currently the most stringent standard for verifying emission reductions, and thus, the credits are currently worth more than on the other markets (Penque and Belcher, 2009). The CCAR methodology calculates emission reductions by taking the lesser value of the CH_4 destroyed by the offset project (anaerobic digester) and the difference between the baseline emissions and the project-related emissions. The methodology states, “In the case that the total ex-post quantity of metered and destroyed methane is less than the modeled methane reductions, the metered quantity of destroyed methane will replace the modeled methane reductions” (CCAR, 2008). The CCAR methodology uses a factor of 21 for the GWP of CH_4. This methodology may yield comparatively higher baseline emissions for projects in colder climates, due to the procedure used to estimate VS degradation in the long-term storage. The CCAR methodology results in comparatively conservative values of reductions when compared with the other methodologies, due to the stringent monitoring procedures (Penque and Belcher, 2009).

5.4.4 Power Profiler

Power Profiler is an online tool developed by the EPA to estimate the air emission impacts of the electricity used in a particular home/business. Power Profiler can be used to calculate the avoided emissions by using renewable electricity produced on-farm through anaerobic digestion CHP, rather than purchasing fossil fuel-generated electricity. It can be found at: www.epa.gov/cleanenergy/energy-and-you/how-clean.html. The tool can be used in conjunction with each of the emission-reduction methodologies since they do not account for offset fossil fuel-based electricity.

5.4.5 Case Study

A review was performed for each methodology previously mentioned using actual data from two operating on-farm digesters in NY. Table 7 shows the average value of each methodology (EPA Climate Leaders, RGGI and CCAR) plus the emission reductions estimated by Power Profiler, for each of the two digester systems analyzed. It is increasingly popular to put emission reductions of all forms on an equivalent number of cars removed from the road. This value is shown in Table 7 for each farm, based on the EPA estimate that a typical passenger vehicle emits 5.5 TCO_2e/year (U.S. EPA, 2005). It is helpful for producers to see effects on a per-cow basis, thus, the number of cars removed for each lactating cow equivalent (LCE) also is shown in Table 7.

Table 7. Comparison of Farm Emission Reduction Data

	New Hope View Farm	Patterson Farm
Average reduction estimation	5,624 TCO_2e/year	9,009 TCO_2e/year
Equivalent # cars removed from road	1,023 cars	1,638 cars
# cars removed/LCE	1.0	1.5

Also interesting to note is the economic effect of each methodology’s outcome. Table 8 shows what would be an annual offset payment amount according to each methodology on each farm. Instead of using a value from one of the carbon trading markets, the March 2009 carbon value of \$5.20/tonne CO_2e from the Voluntary Carbon Index was used (New Carbon, 2009). This value represents an average of all the markets in North America that trade voluntarily reduced GHG emissions. Also shown in Table 8 are the average offset payments, and the average offset payment per LCE. Because each reduction calculation method results in a different estimation of GHG reductions, the offset payment amount is significantly affected. New Hope View Farm could receive from \$19,335 per year to \$36,433 per year, while Patterson Farm could receive from \$21,384 per year to \$81,851 per year due to the differing calculations to determine emission reductions.

Table 8. Offset Payments for Each Methodology for Both Farms

	New Hope View Farm Offset Payment	Patterson Farm Offset Payment
EPA Climate Leaders	$25,922	$23,577
EPA Climate Leaders (including food waste considerations)	--	$21,384
RGGI	$19,335	$26,743
CCAR	$36,433	$81,851
Average[1]	$29,245	$46,846
Power Profiler	$2,015	$2,790
Offset Payment/LCE (not accounting for food waste)	$27.77	$43.66

[1]Average taken of the Climate Leaders (without food waste consideration), RGGI and CCAR, with Power Profiler added to the overall average.

Meaningful revenue from GHG offset projects has the potential to make AD projects more attractive economically, and more viable for farms to implement.

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Appendices

APPENDIX 1. GLOSSARY FOR NEW YORK MANURE-BASED ANAEROBIC DIGESTION

Anaerobic bacteria

Microorganisms that live and reproduce in an environment containing no “free” or dissolved oxygen. Used for anaerobic digestion.

Anaerobic digester (AD)

A specifically designed vessel and associated heating and gas collection system to contain biomass under digestion and its associated microbially produced biogas. Particular conditions provided by the digester are oxygen-free, constant temperature and sufficient biomass retention time.

Anaerobic digestion (AD)

A biological process in which microbes “digest” the organic material in manure while giving off biogas as a byproduct.

Anaerobic lagoon

A holding pond for livestock manure that is designed to anaerobically stabilize manure, and may be designed to capture biogas with the use of an impermeable, floating cover.

Aspect ratio

A relationship between the length and width of a rectangle, expressed as length:width. The aspect ratio of a square is 1:1.

Biogas

For the purposes of this document, the raw and uncleaned gas coming directly from the anaerobic digester, consisting of mainly CH_4 (60%) and CO_2 (40%).

Bioreactor

Vessel or tank in which whole cells or cell-free enzymes transform raw materials into biochemical products and/or less undesirable products.

Biosolids

The waste material from animal or vegetable sources. Waste contains mainly carbon and hydrogen.

Black start

The process of starting and operating an on-site engine-generator set without relying on external energy sources.

British Thermal Unit (Btu)

The standard measure of heat energy. It takes one Btu to raise the temperature of one pound of water by one degree Fahrenheit at sea level. For example, it takes about 2,000 Btus to make a pot of coffee. One Btu is equivalent to 252 calories, 778 foot-pounds, 1,055 joules and 0.293 watt-hours.

Capacity factor

The ratio of the net energy generated, for the period of time considered, to the energy that could have been generated at continuous full-power operation during the same period.

Capital cost

The cost of field development and plant construction and the equipment required for the generation of electricity.

Centralized digester

An anaerobic digester that uses feedstock based on manure from several individual farms within a relatively proximate distance to the digester location.

Co-firing

The use of two or more different fuels (e.g., wood and coal) simultaneously in the same combustion chamber of a power plant.

Co-generation

The sequential use of energy for the production of electrical and useful thermal energy. The sequence can be thermal use followed by power production or the reverse, subject to the following standards: (a) At least 5% of the co-generation project's total annual energy output shall be in the form of useful thermal energy and (b) Where useful thermal energy follows power production, the useful annual power output plus one-half the useful annual thermal energy output equals not less than 42.5% of any natural gas and oil energy input.

Combined heat and power (CHP)

The sequential or simultaneous generation of two different forms of useful energy — mechanical and thermal — from a single primary energy source in a single, integrated system. CHP systems usually consist of a prime mover, a generator, a heat recovery system, and electrical interconnections configured into an integrated whole.

Combustion turbine

A turbine that generates power from the combustion of a fuel.

Complete mix digester

An anaerobic digester vessel that is mixed with one or several mixing units.

Contact digester (fixed film)

High-rate complete mix or plug-flow digester, which is operated in the thermophilic or mesophilic range to treat dilute and concentrated waste in a contact reactor.

Contact reactor

A high rate process that retains bacterial biomass by separating and concentrating the solids in a separate reactor and returning the solids to the influent. More of the degradable waste can be converted to gas since a substantial portion of the bacterial mass is conserved.

Covered lagoon

Anaerobic digester that consists of a storage lagoon with an impermeable cover, which traps gas produced during the decomposition of waste. The contents of a covered lagoon are neither mixed nor heated.

Customer-sited Tier

Distributed renewable energy systems that are located on or in close proximity to an electrical power consumer that uses the power generated by the system. Farm-based anaerobic digester systems generally fall into this category. (Also known as “behind the meter” or on-site generation).

Demand charge

Utility charge based on readings from a meter that measures the highest average kilowatt demand in a 15-minute period for each billing period.

Dewater

To drain or remove water from an enclosure. A structure may be dewatered so that it can be inspected or repaired. Dewater also means draining or removing water from sludge to increase the solids concentration.

Digestate

Solid material remaining after the anaerobic digestion of a biodegradable feedstock. Digestate is produced both by acidogenesis and methanogenesis, and each have different characteristics.

Digester biogas

The gas containing methane produced from anaerobic digestion of animal or other organic wastes.

Discount rate

The interest rate used in discounting future cash flows.

Distributed generation

A distributed generation system involves small amounts of generation located on a utility’s distribution system for the purpose of meeting local (substation level) peak loads.

Distribution system (electric utility)

The substations, transformers and lines that convey electricity from high-power transmission lines to ultimate consumers.

Effluent

Material exiting the anaerobic digester vessel.

Electric utility

Any person or state agency with a monopoly franchise that sells electric energy to end-use consumers.

Emission

The release or discharge of a substance into the environment; generally refers to the release of gases or particulates into the air.

End-use sectors

The residential, commercial, transportation and industrial sectors of the economy.

Energy consumption

The amount of energy consumed in the form in which it is acquired by the user. The term excludes electrical generation and distribution losses.

Engine-generator set

The combination of an internal combustion engine and generator for the production of electricity. May be single- or dual-fueled depending on the location and setup.

Flare

A device used to safely combust extra or unused biogas.

Flush flume

A method of hydraulically transporting scraped barn manure and soiled bedding from a barn to storage or manure treatment device.

Flush system

A method of hydraulically cleaning manure and soiled bedding from freestall barn alleys.

Food waste

A substrate that can be added to an anaerobic digester to enhance biogas production capabilities.

Generation

Of the three components involved in making energy available for the end user, the state in which energy is produced.

Generator

A device for converting mechanical energy to electrical energy.

Greenhouse gas (GHG)

A gas, such as carbon dioxide or methane, which contributes to potential climate change.

Grid

The electric utility company's transmission and distribution system that links power plants to customers through high-power transmission line service; high voltage primary service for industrial applications; medium voltage primary service for commercial and industrial applications; and secondary service for commercial and residential customers. Grid also can refer to the layout of a gas distribution system of a city or town.

Hydraulic retention time (HRT)

The length of time organic material remains in the anaerobic digester.

Hydrogen sulfide (H_2S)

A toxic, colorless gas that has an offensive odor of rotten eggs and is soluble in water and alcohol. Hydrogen sulfide is a dangerous fire and explosion hazard, and a strong irritant.

Hydrolysis

A chemical decomposition process that uses water to split chemical bonds of substances.

Influent

Liquid flow into a treatment, storage or transfer device.

Installed capacity

The total capacity of electrical generation devices in a power station or system.

Kilowatt-hour (kWh)

The most commonly used unit of measure telling the amount of electricity consumed over time. It means one kilowatt of electricity supplied for one hour.

Lagoon

In wastewater treatment or livestock facilities, a shallow pond used to store wastewater where sunlight and biological activity decompose the waste.

Leachate

Liquids that have percolated through a soil and that carry substances in solution or suspension.

Lost capital

The portion of a capital investment that cannot be recovered after the investment is made, usually used to express the immediate loss in value of a purchased or constructed item.

Main Tier

Distributed renewable energy systems where the electrical power produced is not used on-site but rather transported to the grid for use elsewhere. Wind generation generally falls into this category.

Manure

Material exiting a barn structure, generally consisting of animal excrement (urine and feces) and as used bedding material.

Methane (CH_4)

A flammable, explosive, colorless, odorless, tasteless gas that is slightly soluble in water and soluble in alcohol. Methane is a major constituent of natural gas, and is used as a source of petrochemicals and as a fuel.

Methanogens

Active in Phase 2 of the digestion process, acids (mainly acetic and propionic acids) produced in Phase 1 are converted into biogas by methane-forming bacteria.

Microturbine

A small combustion turbine with a power output ranging from 25 to 500 kW. Microturbines are composed of a compressor, combustor, turbine, alternator, recuperator and generator.

Net generation

Gross generation minus the energy consumed at the generating station for its use.

Net metering

A billing practice used by utilities for certain customers who generate electricity. “Net” refers to the difference between the electricity sold to the customer-generator by the utility and the electricity purchased by the utility from that customer-generator.

NOx

Oxides of nitrogen are a family of reactive gaseous compounds that contribute to air pollution in both urban and rural environments. NOx emissions are produced during the combustion of fuels at high temperatures. The primary sources of atmospheric NOx include highway sources (light-duty and heavy-duty vehicles), non-road sources (construction and agricultural equipment) and stationary sources (power plants and industrial boilers). NOx can irritate the lungs and also are an important precursor both to ozone and acid rain.

Net Present Value (NPV)

The present value of an investment's future net cash flows minus the initial investment. Generally, if the NPV of an investment is positive, the investment should be made.

Operating pressure

Pressure of the gas system or digester during normal operation.

Operation and maintenance (O&M) costs

Operating expenses are associated with operating a facility. Maintenance expenses are that portion of expenses consisting of labor, materials, and other direct and indirect expenses incurred for preserving the operating efficiency or physical condition of utility plants that are used for power production, transmission and distribution of energy.

pH

An expression of the intensity of the alkaline or acidic strength of water. Values range from 0 to 14 where 0 is the most acidic, 14 is the most alkaline, and 7 is neutral.

Plug-flow digester

A design for an anaerobic digester where the material enters at one end and is theoretically pushed in plugs towards the other end, where the material exits the digester after being digested over the design HRT.

Power plant

A facility containing prime movers, electric generators and other equipment for producing electric energy.

Present value

The current value of one or more future cash payments, discounted at some appropriate interest rate.

Rate of return

The annual return on an investment, expressed as a percentage of the total amount invested.

RD&D

Research, development and demonstration.

Renewable resources

Naturally replenishable, but flow-limited energy resources. They are virtually inexhaustible in duration but limited in the amount of energy that is available per unit of time. Some resources may be stock-limited in that stocks are depleted by use, but on a time scale of decades, or perhaps centuries, they can probably be replenished.

Renewable energy resources include: biomass, hydro, geothermal, solar and wind. In the future they also could include the use of ocean thermal, wave and tidal action technologies. Utility renewable resource applications include bulk electricity generation, on-site electricity generation, distributed electricity generation, non-grid connected generation, and demand-reduction (energy efficiency) technologies.

Self-generation

A generation facility dedicated to serving a particular retail customer, usually located on the customer's premises. The facility may either be owned directly by the retail customer or owned by a third party with a contractual arrangement to provide electricity to meet some or all of the customer's load.

Service charge

Each metered service has a basic service charge that utilities bill for that service. This charge is above and beyond the energy and delivery charges that are a function of use at that site.

Siloxane

Any of a class of organic or inorganic chemical compounds of silicon, oxygen, and usually carbon and hydrogen, based on the structural unit R_2SiO where R is an alkyl group, usually methyl.

Stirling engine

An external combustion engine that converts heat into useable mechanical energy by the heating (expanding) and cooling (contracting) of a captive gas such as helium or hydrogen.

Substation

A facility used for switching and/or changing or regulating the voltage of electricity. Service equipment, line transformer installations, or minor distribution or transmission equipment are not classified as substations.

Tail gas

The gas flow from a biogas clean-up system that contains removed contaminates and some low levels of methane.

Tipping fees

Monies that are paid to the site with an anaerobic digester that is accepting outside sources of organic material (food waste).

Ton

U.S. short ton equals 2,000 lbs

Tonne

Metric ton equals 1,000 kg.

Total dissolved solids (TDS)

The total amount in milligrams of solid material dissolved in one liter of water (mg/L).

Transmission

Movement of bulk energy sources (electricity) from the generation facility (power plant) to a distribution facility.

Transmission and distribution (T&D) system

An interconnected group of electric transmission lines and associated equipment for the movement or transfer of electric energy in bulk between points of supply and points at which it is transformed for delivery to the ultimate customer(s).

Transmission lines

Lines that transmit high-voltage electricity from the transformer to the electric distribution system.

Transportation sector

Private and public vehicles that move people and commodities. Included are automobiles, trucks, buses, motorcycles, railroads, railways, aircraft, ships, barges and natural gas pipelines.

Treatment volume

Inside volume of the AD that, under normal operating conditions, would be full of material undergoing anaerobic decomposition.

Turbine

A device for converting the flow of a fluid (air, steam, water or hot gases) into mechanical motion.

Utility service class

A utility-based differentiation between rate-paying customers based on size and classification (residential, commercial, industrial, etc.) that results in varied billing procedures.

Volatile solids

Those solids in water or other liquids that are lost on ignition of the dry solids at 550 degrees centigrade.

Volt

A unit of electrical pressure. It measures the force or push of electricity. Volts represent pressure, correspondent to the pressure of water in a pipe. A volt is the unit of electromotive force or electric pressure analogous to water pressure in pounds per square inch. It is the electromotive force which, if steadily applied to a circuit having a resistance of one ohm, will produce a current of one ampere.

Watt

A standard unit of measure for the rate at which energy is consumed by equipment or the rate at which energy moves from one location to another. It is also the standard unit of measure for electrical power.

Watt-hour

A standard unit of measure for the amount of energy that is consumed by equipment, the amount of embodied energy or the amount of energy moved from one location to another. It also is the standard unit of measure for electrical use. Generally expressed in 1,000 watt-hr increments or kWh.

Appendix 1 Reference:

Public Interest Energy Research. 2006. Glossary of energy terms. Web address: www.pierminigrid.org/glossary.html

APPENDIX 2. LIST OF ABBREVIATIONS

AD	Anaerobic digestion
BMP (1)	Best management practice
BMP (2)	Biochemical methane potential
BOD	Biological oxygen demand
Btu	British thermal unit (mmBtu = 1 x 10^6 Btu), (TBtu = 1 x 10^{12} Btu)
CAFO	Concentrated Animal Feeding Operation
cfm	Cubic feet per minute
cfu/mg	Colony forming unit/milligram
CNMP	Comprehensive Nutrient Management Plan
CBM	Compressed bio-methane
CH_4	Methane
CHP	Combined heat and power
CNG	Compressed natural gas
CO_2	Carbon dioxide
COD	Chemical oxygen demand
Decatherm	1 mmBtu
ESP	Electrical service provider
FOG	Fats, oils and greases
ft^3	Cubic foot
Gal	U.S. gallon (3.8 liters)
GHG	Greenhouse gas
GWh	Gigawatt hours
GWP	Global warming potential
H_2	Hydrogen
H_2S	Hydrogen sulfide
HRT	Hydraulic retention time
Kg	Kilogram
kVA	Kilovolt amps
kW	Kilowatt
kWh	Kilowatt-hour
L	Liter
Lb	U.S. pound
LNG	Liquefied natural gas
m^3	Cubic meter
Mmscf	Million standard cubic feet
MW	Megawatt
MWh	Megawatt hours
N_2	Nitrogen
N_2O	Nitrous oxide
NH_3	Ammonia
NPK	Nitrogen, phosphorus and potassium content of fertilizer
NY and NYS	New York State
OLR	Organic loading rate
PPA	Power Purchase Agreement
REC	Renewable energy credit
RGGI	Regional Greenhouse Gas Initiative
RPS	Renewable portfolio standard
TSS	Total suspended solids
TOU	Time of Use

SCFM	Standard cubic feet per minute (adjusted for temperature and pressure)
SLDM	Sand-laden dairy manure
SLS	Solid-liquid separator
SPDES	State Pollutant Discharge Elimination System
VFA	Volatile fatty acids
VS	Volatile solids
VSS	Suspended volatile solids

Organizations

DPS	Department of Public Service
FERC	Federal Energy Regulatory Commission
NRCS	Natural Resources Conservation Service
NYISO	New York Independent System Operator
NYSDEC	New York State Department of Environmental Conservation
NYSEG	New York State Electric and Gas
NYSERDA	New York State Energy Research and Development Authority
PSC	Public Service Commission
RG&E	Rochester Gas and Electric

APPENDIX 3. OVERVIEW OF ANAEROBIC DIGESTION SYSTEMS FOR DAIRY FARMS

The proper viewpoint on AD is one that recognizes that AD is a viable component of an overall manure treatment and handling system for many, but not all, dairy farms. A systems-based perspective of AD is one that not only looks at the advantages and disadvantages of AD itself but also how AD overall affects the farm from all pertinent perspectives. This approach is imperative in today's dairy industry and environmental regulatory climate as each are dynamic and change is driven by forces outside of the dairy producer's control.

From the dairy-manure-based operator's perspective, digesters should be thought of as an extension of a cow's stomach. Both rely on operative microbes to transform foodstuff into useable energy, and the operative microbes are most successful at doing this when they are consistently fed a diet that meets their nutritional needs.

The goal of this appendix is to provide a general overview of dairy manure-based AD systems.

Anaerobic Digestion: The Microbial Process

AD is a microbially mediated process where multiple groups of operative microbes work together in a sequential fashion resulting in the conversion of a portion of the organic matter into biogas as shown in Figure 10. The complex organic material in manure and other biomass sources is broken down by microorganisms in the absence of oxygen (anaerobic). The end products are methane (CH_4), carbon dioxide (CO_2), some trace gases, and a stabilized, mostly liquid effluent.

This process occurs naturally in many existing manure storages, especially those that store untreated manure long-term. Unfortunately in most natural situations the process does not go to completion and many of the intermediate products are quite odiferous.

The overall process involves three groups of anaerobic microbes. First, hydrolytic bacteria initiate a process called hydrolysis. These bacteria use extra cellular enzymes to convert organic insoluble fibrous material into soluble material; however, inorganic solids and hard-to-digest organic material are not able to be converted.

Next, acid-forming bacteria convert the soluble carbohydrates, fats and proteins to short-chained organic acids. The acids produced in step two become the food source for the methanogens, which produce the methane gas.

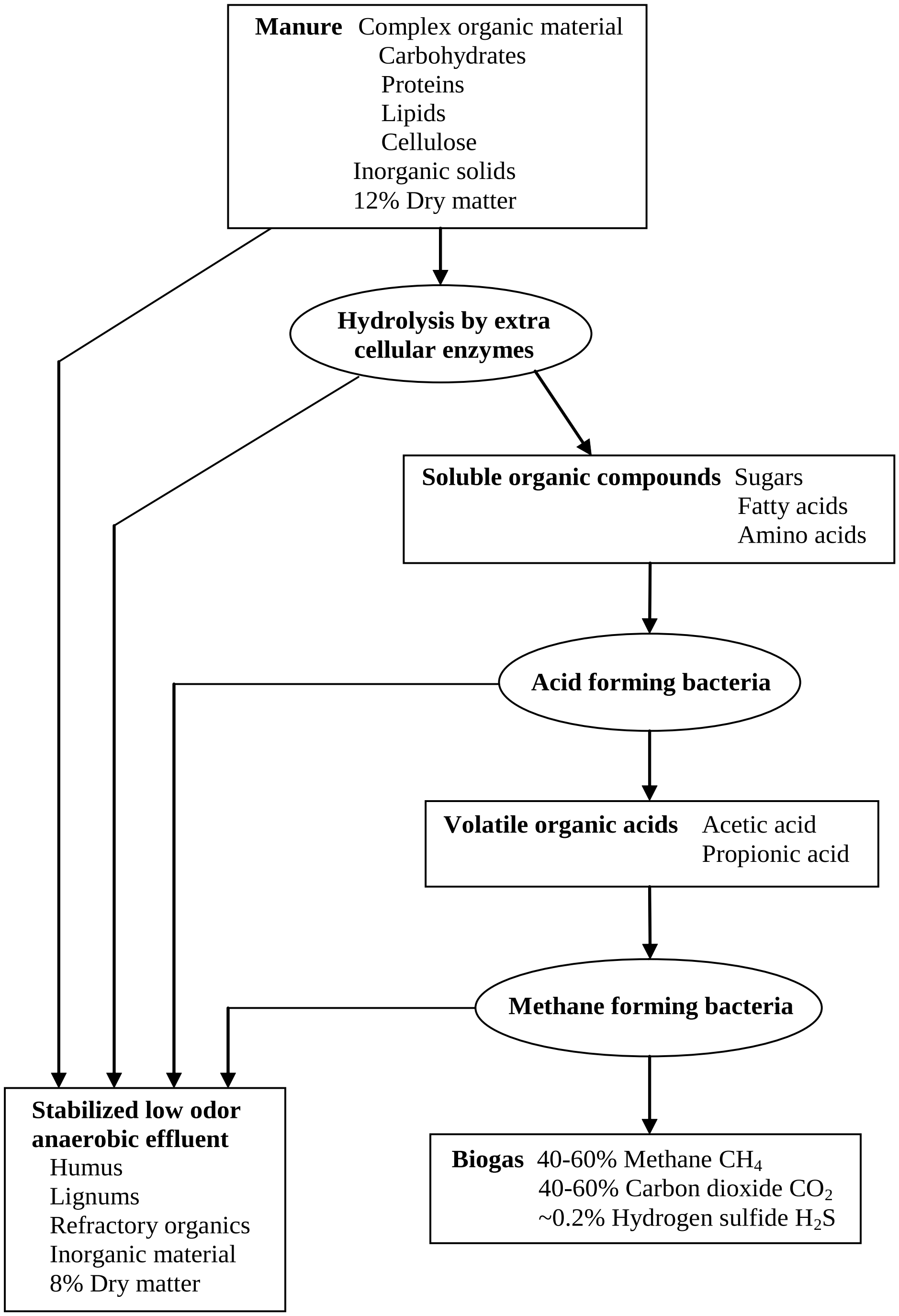

Figure 10. Anaerobic digestion of dairy manure.

Methanogens: The Key Microbe

Of the overall microbial processing chain, the methanogens are the weakest link. This is because methanogens:

- Are the most sensitive to pH (prefer 6 to 8 with optimal at 7)
- Are the most sensitive to digester temperature changes
- Cannot tolerate oxygen
- Need simple organic acids for food
- Are the least robust of the operative microbes
- Grow slowly compared with the other operative microbes

Digesters need to be able to retain sufficient populations of methanogens to complete the breakdown of the acids and produce the methane. It is very important that an AD designer consider the environment within the digester to be sure the pH, temperature and retention time is appropriate allowing for a sufficient population of methanogens to convert microbial-generated acids to biogas.

Various methanogenic species grow in different temperature regimes.

1. Psychrophilic methanogens grow in the lowest of the temperature ranges, less than 68°F. Methanogens in this range grow slowest and produce the least biogas per unit of time. Covered lagoon systems, especially those in Northern climates, will be in this range much of the year (Wright, 2001).

2. Mesophillic methanogens grow in an optimum temperature of about 100°F and is the most common operational temperature for digesters in the U.S.

3. Thermophillic methanogens grow in an optimum temperature of about 130°F. A review of European digester systems revealed that the rate of biogas production per unit of time exists when thermophillic microbes are active. The higher operating temperature also increases pathogen reduction, and allows for shorter retention times, thus reducing the capital cost of the digester vessel.

Digester Types

In the U.S. there are basically three different types of on-farm AD systems: plug-flow, complete mix and covered lagoon. Of these three, two are appropriate for NY: the plug-flow and complete mix systems.

Covered lagoons, not to be confused with covered manure storages, are systems used in warm and hot climates were biological treatment lagoons are designed to treat flush water effluent from freestall barns.

Plug-flow and complete mix (both horizontal and vertical versions) AD systems are discussed in detail below.

Plug-Flow Anaerobic Digester Systems

The first ADs constructed on dairy farms in the U.S. were plug-flow digesters, and subsequently many systems have been built and are operational in NY, all basically like the one shown in Figure 11. The primary reason for their competitively wide-span adoption is plug-flow digesters are comparatively low in equipment and operating costs (not necessarily overall costs) to compared with complete mix digesters.

Figure 11. A horizontal plug-flow digester with a flexible top membrane located in Cortland County.

The theory of plug-flow digesters is just as the name suggests; influent material is introduced at one end of the digester and flows linearly, like a plug, through the digester and exits at a point of time in the future that equals the digester's hydraulic retention time (HRT). The design HRT in most plug-flow digesters is about 21 days; HRT is calculated by dividing the digester treatment volume by the average daily volume of influent digested. The aspect ratio for plug-flow digesters normally ranges from 4:1 to 6:1.

A key to the success of this system is correct moisture content (12% TS or very close thereto) of the influent material. Influent that is too dry will not flow properly through the digester and material that is too wet will result in the partitioning of some solids (some will settle and some will float).

Plug-flow digesters are generally constructed below-grade using poured-in-place concrete to construct the digester vessel. Insulation is added to the exterior walls of the vessel before backfilling to reduce the system's parasitic heat load. The tops are either concrete (either pre-cast or poured-in-place) or flexible membrane.

Complete Mix Digester, Horizontal System

Horizontal-mix digesters incorporate agitation systems in plug-flow digester vessels. The mixing system is mainly utilized in scenarios that have TS concentrations greater than 12% (not common with dairy manure-based systems) or less than 10%. Digester influent concentrations less than 10% TS are common when co-digesting manure with imported food wastes.

In NY, many farmers are interested in mixing food wastes with manure due to:

1. The increased biogas production potential the mixture produces.

2. The associated tipping fees for allowing food waste generators to unload their byproduct on the farm.

Food waste generally has a lower solid content than raw manure, so when combined with manure the resulting mixture needs to be mixed in the digester to help keep the solids in suspension.

The electrical demand of the mixing units should be given due consideration when designing a mixed plug-flow system. The electrical energy the agitators consume increases the system's overall parasitic load, thus reducing the net energy available for sale to the electrical grid.

The HRT of mixed digesters varies at the micro level from manure particle to manure particle. Some particles of manure will remain in the digester for greater than the theoretical HRT while some will short-circuit due to the agitation process and exit sooner. In Denmark, mixing of food waste with manure is common practice and the Danish government requires the food waste and manure mixture be pasteurized (70°C for one hour) prior to being land-applied in order for the farm to be in compliance with standard manure application laws.

In NY, farms are limited by the Net Metering law to importing no more than 50% (by weight of the total digester influent) food waste for digestion with manure. Food waste contains nutrients (nitrogen, phosphorus and potassium) that must be considered when assessing the impact importing food waste has on the farm's ability to comply with its CNMP. Technologies originally developed for treating municipal wastewater are readily available for removing excessive phosphorus from manure (and a manure-food waste blend), but the economics of the implementation of such systems on-farm is not well established. More work is required in the area of evaluating the overall sustainability of on-farm digestion of food wastes.

Complete Mix Digester, Vertical System

Vertical mixed digester tanks can be either below-grade (atypical) or above-grade (typical) as shown in Figure 12. Tanks constructed above-grade have less lateral load applied to the sidewall than those constructed below-grade. Cast-in-place concrete, welded steel, bolted stainless steel, and glass-lined steel panels are all used to construct vertical tanks. Vertical tank digesters in the U.S. are predominantly used when dilute digester influent (total solids (TS) less than 10%) is involved.

Figure 12. Above-grade complete mix vertical digester on a Wisconsin dairy farm.

The mixing process is achieved by various methods, depending on the preference of the system designer and the overall goals of the system. In one method, an external electrical motor (about 20 hp) turns a vertical shaft, concentric with the digester tank, that has several large paddles attached. The shaft speed is about 20 rpms. This system is common for solid top tanks. Another method uses submersed impeller agitators, each driven by either an electrical motor or a centrally located hydraulic motor. These systems have a much higher blade speed, perhaps 1,750 rpms, and can be used with both flexible top and solid top applications. One clear advantage of the first method is the electrical motor is easy to service and replace. Also, there is some thought that the higher speed impeller agitators negatively affect the operative microbes, but this does not appear to have been proven at this time.

Vertical tanks are insulated during the construction process to minimize the maintenance heating requirement (heat to maintain digester operating temperature). Significant heat can be lost from vertical tank digesters if they are not properly insulated. Applicable insulation options are to spray the tank with foam insulation or to use rigid board insulation attached to the tank and then covered with metal cladding. In either case, it seems the typical insulation thickness used in most installations is four to five inches.

Fixed-film

A fixed-film AD is a digester that contains media within the treatment volume of the digestion vessel. The purpose of the media is to provide surface area for operative microbes to grow and propagate with the overall goal of reducing the HRT while maintaining a reasonable level of biogas production. The media can be constructed of plastic, polypropylene or other non-degradable materials.

Digesters using fixed-film technology are targeted to treat dilute slurries such as the liquid effluent from a solid-liquid separator (about 5% TS) or from an alley flush or flush flume conveyance system (1% TS or less). The HRT is usually three to five days.

A fixed-film AD in NY operated successfully for 18 months without incidence (Figure 13).

During the operational period, it was found that sufficient biogas production existed to maintain the digester at target operating temperature (100°F) during the winter months. The generated biogas was used to fire a boiler that in turn provided heat to a shell and tube heat exchanger for digester heating.

In another example, a larger fixed-film digester has been in operation for several years at the 600-cow University of Florida dairy research farm near Gainesville, Fla. A flush system is used to convey sand-laden dairy manure from the barns to a passive sand-manure separation system, where sand is settled and subsequently removed. Effluent from the sand separation system is processed in a fixed-film digester. This digester operates at near ambient temperature; no supplemental heat is provided. The system would not be appropriate for NY due to the lack of a heating system. If a heating system were added, the parasitic heat load associated with warming digester influent to operating temperature would not be met by the heat value of the biogas generated.

Centralized Digestion

Centralized digestion, the practice of strategically locating an AD in proximity to multiple farms, is attractive mainly due to the economies of scale possible, potentially lowering the capital investment required per cow. Another reason farmers have considered centralized digestion is that these systems may have the size needed to justify and pay for a full-time crew to operate them. Several feasibility studies have been conducted in NY to look at the practice and economics of centralized digestion, including the Salem Feasibility Study (Washington County) and the Perry Feasibility Study (Wyoming County). Overall, the common findings of these feasibility studies were:

- Biosecurity concerns — There was no way to prevent the commingling of sourced manure and digester effluent needed to be returned to the source farms.

- Economics — The proposed systems were not found to be economically feasible at the time the study was conducted. Manure trucking costs were a large component of the estimated annual operating cost.

- Energy production — The estimated energy production of the system was beyond the needs of the target buyer (a feed mill) and the utility was not interested in paying a higher price for the renewable power.

- Odor — Concern was expressed about the potential for significant odor emissions while trucking raw manure to the centralized digester site.

Figure 13. A vertical fixed-film digester located on a 100-cow tie stall farm in the Catskill region of NY

Biogas Composition

On-farm digester monitoring has shown that biogas is comprised mainly of 60% methane and 40% carbon dioxide as shown in Figure 14. Pure (dry) methane has a heating value of 896 Btu/ft^3 (at standard temperature and pressure: 32°F and 1 Atm) (Marks, 1941). Since biogas is only 60% methane, its heating value is 40% lower at about 540 Btu/ft^3.

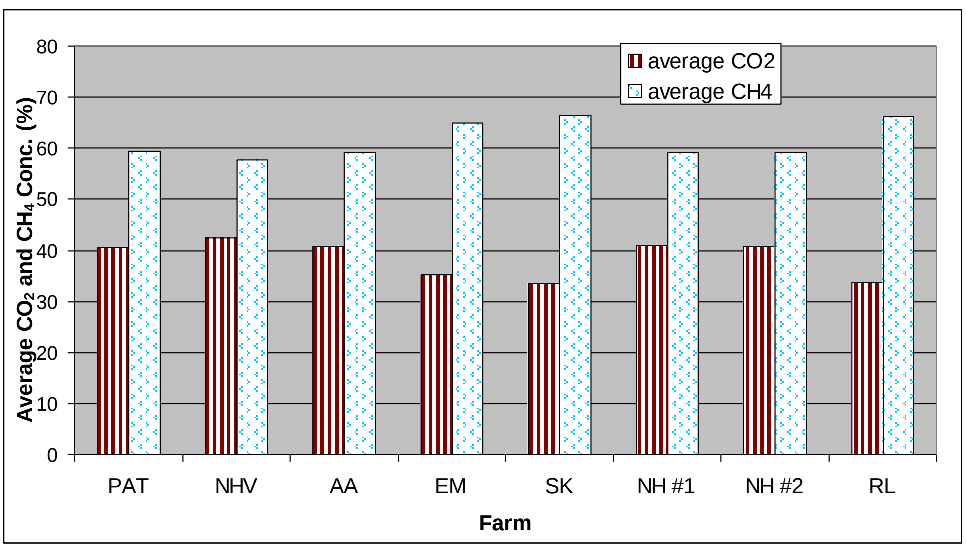

Figure 14. Carbon dioxide and methane concentrations from several NY anaerobic digesters.

In a properly managed plug-flow digester, a biogas production of at least 1.5 ft^3/day/ft^3 of digester treatment volume can be expected (Koelsch et al., undated). Production of biogas is dependent on the digester HRT and the biochemical energy potential of the influent. Biochemical energy of an influent material is most accurately evaluated by conducting long-term (six-month) bench-top reactor tests (Angenent, 2009) but is generally estimated by measuring the volatile solids content in the influent. Jewell (2007) indicated that an appropriate estimation of the methane production is to use a value of 0.5 L CH_4/gram of VS degraded. If the biogas is 60% CH_4, this translates to 13.4 ft^3 biogas/lb. of VS degraded.

Utilization: fuel source for engine-generator sets

Using biogas as an energy source to fire on-site engine-generator sets is the most common use of biogas today. Large engines that had been adopted for landfill biogas years ago are now available for use on dairy farms. Most are spark-ignited systems with a few compression- ignited systems that also use about 10% diesel fuel concurrently as a fuel source.

Overall, these “low Btu - dirty gas” engines work well with the exception of difficulties arising from hydrogen sulfide (H_2S). Dairy manure biogas typically contains 0.2% to 0.4% H_2S. Hydrogen sulfide is very corrosive at low temperatures since it converts to sulfuric acid. To date, most on-farm biogas-fired engines combat the corrosiveness by changing oil more frequently than for cleaner fuel source scenarios. Recently, some U.S. farmers have installed scrubbers to remove H_2S from biogas prior to utilization. Scrubbers come in various designs, including chemical reaction, biological reduction, wet washing and molecular sieve separation. Scrubbers are mainstream equipment on European digester systems.

Overall, there are two basic types of generators:

1. Induction generators run off the signal from the utility and are used to allow parallel hook-up with the utility. Induction generators cannot be used as a source of on-farm backup power since the system needs the signal from the utility line to operate properly.

2. Synchronous generators could be run independently of the utility but matching the utility’s power signal would be very difficult, so these types of generators would be used if the system were not connected to the utility grid.

Most generator systems manufactured today have controls that will allow the engine-generator set to synchronize with the utility’s electrical frequency and still operate in island mode when there is a disruption of the grid power. These systems can be set up to “black start” if desired.

Thermal to electrical conversion efficiencies for biogas-fired internal combustion engine-generator sets are less than desirable, but are about the same as other fuels. On-farm digester monitoring has shown that the conversion efficiency ranged from 22% to 28% (excluding Farm AA’s conversion data, which is low due to an inordinately old engine-generator set) as shown in Figure 15.

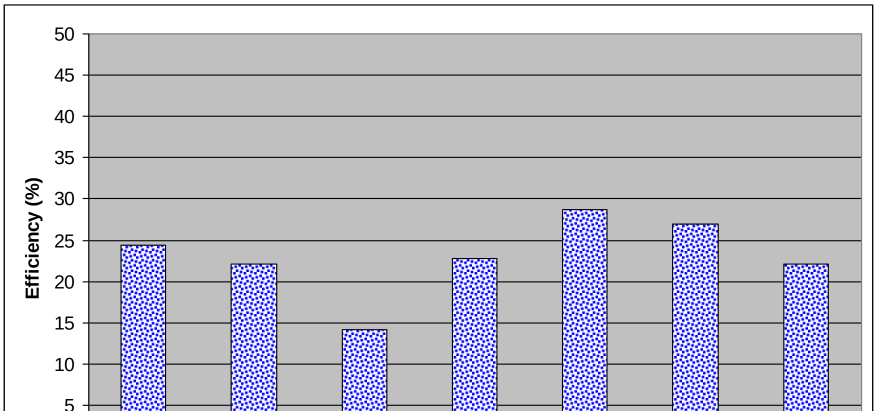

Figure 15. Thermal to electric conversion efficiency of seven NY on-farm engine-generator sets. (Source: Gooch and Pronto, 2009).

The electricity production depends on the amount and quality of gas as well as the efficiency of the engine-generator. Typically, 33 to 38 kWh/day will be produced per 1,000 ft^3/day of biogas produced (Koelsch et al., undated and EPA, 1997). An operation and maintenance cost of $0.015 per kWh is estimated for engine-generators (EPA, 1997).

Engine water jacket heat, and sometimes exhaust heat as well, is harvested and used as the primary means to heat the digester. In the winter, most, if not all, of this harvested heat is needed while in the summer a good portion of it is dumped to the ambient via forced-air/water heat exchanger.

Utilization: fuel source for microturbines

Two NY dairy farms have microturbines to convert biogas to electricity. The main interest in microturbines is the premise that they require less maintenance on a daily and also long-term basis, and most recently that they potentially produce less exhaust emissions. Biogas pressure needs to be increased from typical digester pressure values to about 60 psi before being injected into a microturbine. Small-scale compressors are available to compress raw biogas to this pressure, thus lessening the need for an H_2S scrubber.

Utilization: fuel source for boilers

On-farm biogas utilization by a boiler is the second most popular use of the energy. Natural gas boilers can be slightly modified to use biogas. The main modification involves increasing the pipe delivery size and orifices in the burners to accommodate the lower density fuel. Boilers are mainly used to provide primary or secondary heating of the digester and in some cases also to provide domestic heating of farm offices and lounge areas. One farm used boiler heat to heat a calf barn, but this use is limited.

Utilization: fuel source for other uses

Other immediate possibilities for on-site uses of biogas, are to fuel drying equipment such as grain dryers, and in the future to possibly fuel a fuel cell.

The typical fuel-to-power efficiencies of various biogas utilization options are shown in Table 9. These efficiency figures do not account for increases due to the use of cogenerated heat.

Table 9. Typical Fuel-to-Power Efficiency Values (adapted from Wright, 2001).

Prime Mover Type	Efficiency
Spark ignition engine	18% to 28%
Compression ignition engine (diesel)	30% to35% above 1 MW 25% to 30% below 1 MW
Gas turbine	18% to 40% above 10 MW
Microturbine	25% to 35% below 1 MW
Fuel cell	40% to 60%

Operational Challenges

Experience has shown that on-farm digesters in the U.S. do not operate without occasional malfunctions, and it would be unreasonable for one to expect a complex system such as a digester to do so. Compared with the traditional methods of handling manure on the farm, digesters are complex and involve:

- Physical systems, including containment vessels and influent /effluent pits
- Mechanical equipment, including pumps, agitators and sensors
- Biological systems, including methanogens

The daily success of such a system is deeply rooted in a person who takes ownership in the system and is provided the resources needed to make it successful.

General operational challenges include:

- Changes in influent composition — Adding variable qualities or quantities of influent can allow the acid-forming bacteria to outproduce the methanogens. Acidic conditions can then develop, compromising the stable environment and production of methanogens.
- Influent moisture content too high or too low for plug-flow digesters — A plug-flow digester feedstock with too high a moisture content (>90%) can experience passive separation of solids; some will settle and some will float, resulting in solid retention and consequently reduced HRT over time. Accumulation of floating solids results in a crust forming and subsequently can block the outlet discharge; in essence making the system constipated.
- Foaming — Foaming occurs when rising biogas bubbles do not pop when reaching the manure/biogas headspace interface in the digester. Foaming can be a major issue when feedstock composition or feeding rates change, most notably when new corn silage and/or haylage is fed to cows. Excessive foaming can plug the gas outlet or enter the gas line and gum up pressure regulators or other equipment.
- Temperature — Maintaining the temperature of the digester is critical to ensure efficient operative microbes. In-vessel hot water circulation heating pipes, if operated at too high a temperature, will scald the manure immediately surrounding the pipe and consequently reduce their heat transfer efficiency, resulting in difficulty in maintaining operational temperature. Poorly insulated digesters may lose too much heat in the winter

to maintain temperatures.

- Frozen manure — Near frozen or frozen manure is common much of the winter in NY. Frozen manure needs tremendous energy to thaw it and then to raise it to digester operating temperature. In fact, the requirement can be so high that there is not enough heat to bring the manure up to operating temperature. With lowered temperatures, biogas production decreases, resulting in even less heat being available.

- Control systems — Controls for ADs can be relatively simple but not necessarily effective at making necessary changes in the system. Controls also may be complicated, but better able to make system adjustments. More simple control systems are easier to understand, such as this indication: "turn this valve by hand slightly to increase water flow," but require someone present to make the adjustments as needed. Complicated controls are effective until they fail or the monitoring device that provides input to them fails. Such control systems are not generally able to be serviced by the person in charge of the day-to-day operation of an on-farm digester.

- Safety — Dairy producers are not generally trained in all of the hazard areas common to a digester system. There are safety issues of asphyxiation, fire and explosion associated with the production of biogas. Methane can explode when mixed with air in concentrations of 5% to 15% and a fire hazard exists when there are leaks present in biogas containment materials. Dangerous levels of ammonia and hydrogen sulfide also may be present. The same hazards associated with large engines and electrical generation also are present in these systems.

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APPENDIX 4. AD WATER QUALITY IMPLICATIONS

Long-term storage of dairy manure, comprised of mostly water (90%), organic matter (10%) and nutrients in solid and liquid form, was developed as a best management practice (BMP) several decades ago. The goals of long-term storage include:

1. Eliminating the farmer's daily chore of spreading manure

2. Improving the timeliness of manure spreading, thereby increasing the efficiency of manure nutrient (nitrogen [N], phosphorus [P] and potassium [K]) utilization by field crops

3. Reducing the chance of manure nutrient and pathogen runoff to surface water and infiltration to groundwater

Storing manure long-term is not without challenges. Most notably is the challenge of manure quickly becoming anaerobic (no oxygen); manure-borne microorganisms that live in this condition produce odorous gases that can be offensive to humans. The offensiveness can be significant, to the degree that many farms have challenges storing manure long-term and subsequently spreading it in ways that are least costly and result in the most efficient crop utilization of nutrients.

Anaerobic Digestion and Water Quality
Key benefits of on-farm AD, from a water quality management perspective include the:

1. Reduction of odor emissions

2. Reduction of pathogens

3. Conservation of the manure nutrients N, P and K

These key benefits provide the opportunity for farmers to recycle manure back to their fields for use to grow cow feed in a manner that naturally replenishes the land. Each benefit is briefly discussed below.

Reduction of Odors
Untreated (raw) dairy manure stored long-term quickly becomes void of oxygen and thus undergoes a natural transformation that results in the release of odorous compounds to the ambient environment. While the offensiveness of these odors varies from farm to farm and from person to person, overall, the odorous nature of untreated manure generally limits recycling of manure stored long-term back to the land base during times when no crop is growing.

Odor control for such systems, during times of manure recycling, is achieved by direct incorporation of the manure into the soil profile by heavy tillage equipment. This is the most commonly used method of handling and recycling manure back to the land base today. A shortcoming is the heavy tillage required can only be performed a short time before planting the crop, or in the fall after the crop has been harvested. Manure nutrients recycled to the land base during these times are less utilized by a planted crop than if applied directly to a growing crop, and thus are more apt to create water quality issues.

AD of dairy manure prior to long-term storage reduces the main odor-causing compounds, thus providing the opportunity for treated manure to be more easily stored long-term and most importantly, subsequently applied to a growing crop with surface irrigation equipment. Manure treated by AD and recycled to cropland in this manner substantially reduces water pollution issues of receiving water bodies.

An additional benefit of applying treated manure with spray irrigation equipment is reduced truck/tractor traffic. Reducing equipment usage on roads lessens the dirt and mud tracked on the road, thus decreasing sediment washoff during rainfall events and consequently, in some instances, eliminating turbidity in receiving water bodies.

Reduction of Pathogens

Dairy cow manure is known to contain multiple pathogens (e.g fecal coliform, *E. coli*, *Cryptosporidium parvum, Giardia, Salmonella* spp.) that can adversely affect water quality. Cornell University research has shown that AD of dairy manure significantly reduced the viable concentration of fecal coliform (Wright et al., 2003). The percent change in fecal coliform concentration (cfu/mg) for five farms extensively monitored was 99.9%, 99.7%, 96.3%, 98.4% and 99.5% as shown in Figure 16. Although the destruction of other pathogens present in manure was not studied, the significant fecal coliform reductions can be used to suggest equally high reductions of other pathogens present in dairy manure.

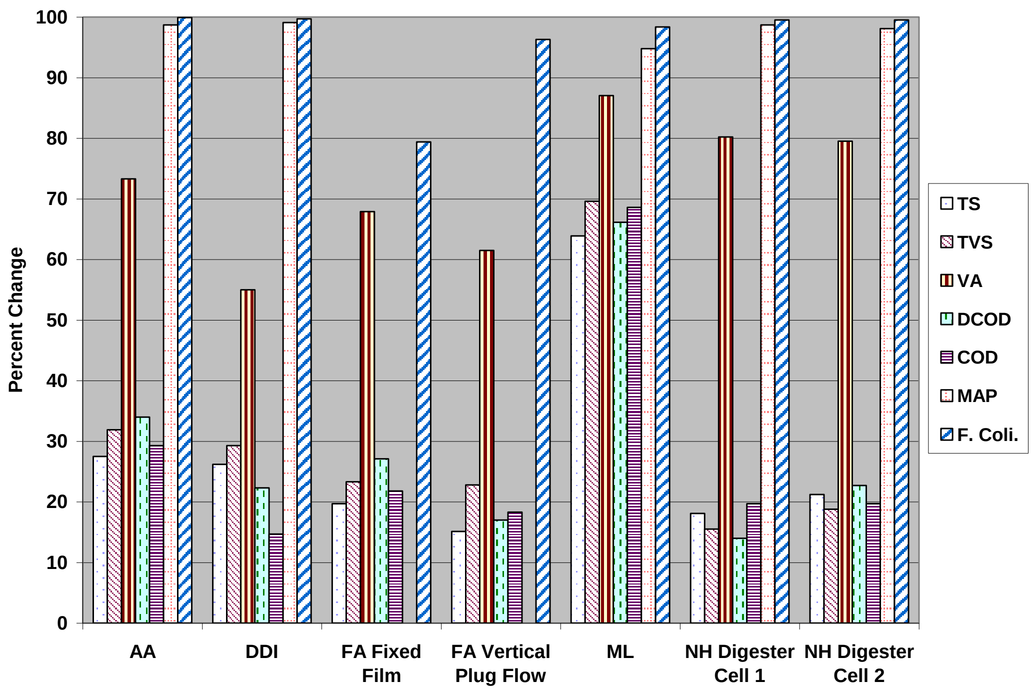

Figure 16. Percent change (reduction) in constituent concentration during AD for each farm. (Source: Gooch et al., 2007)

Conservation of Nitrogen, Phosphorus and Potassium

Dairy cattle manure naturally contains nitrogen (organic-nitrogen and ammonia-nitrogen), phosphorus (in solid and dissolved forms) and potassium. These nutrients are needed by crops, such as corn and alfalfa grown on dairy farms to feed the cows.

AD of dairy cow manure has been shown to conserve the basic elements N, P and K. However, some of the organically bound N and P are converted to soluble form during the digestion process; the soluble form is readily available for plant uptake and utilization. Cornell University research has shown that ammonia-N (NH_3-N) and orthophosphorus (OP) increased on average 23.4% and 15%, respectively, as a result of the AD process at five farms, as shown in Figure 17.

Timely application of stored digester effluent on a growing crop results in a higher percentage of the manure nutrient being used by the crop and thus less available for further transformation to oxidized nitrogen (nitrite-N and nitrate-N).

From a phosphorus standpoint, AD increases the fraction of total phosphorus in a dissolved state, which is the form more available for plant utilization.

Overall, high plant utilization of manure nutrients lessens the impact of water quality from both human health and environmental conservation standpoints.

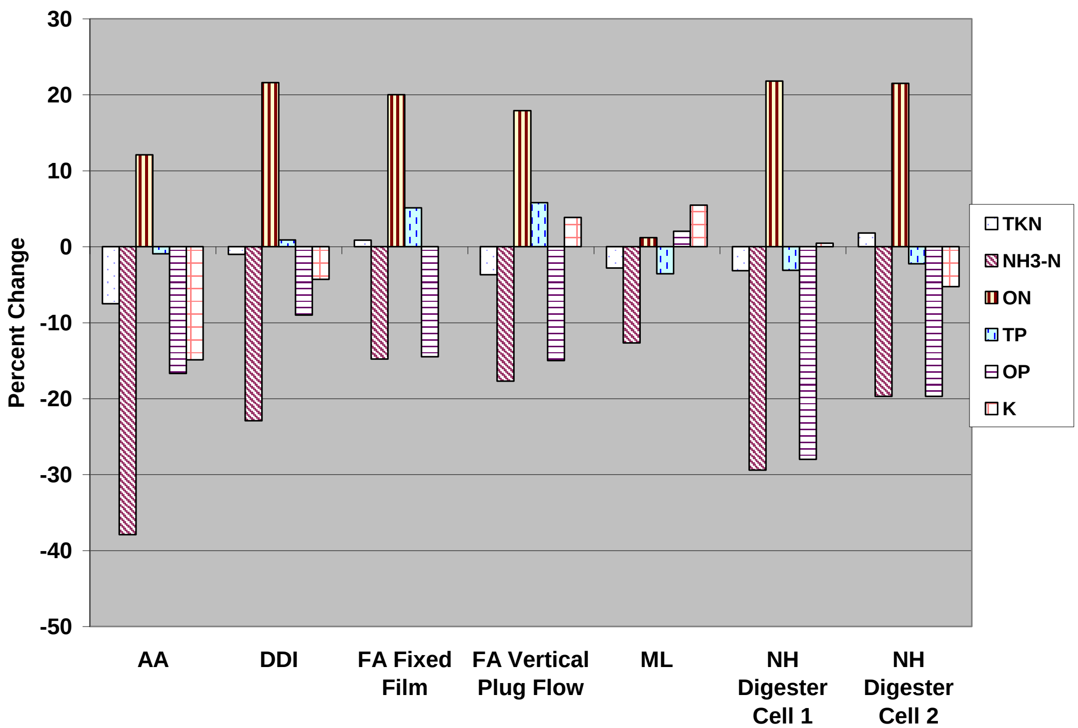

Figure 17. Percent change in constituent concentration during AD for each farm. Negative values represent an increase in the constituent concentration. (Source: Gooch et al., 2007)

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APPENDIX 5. FEASIBILITY STUDIES FOR DAIRY FARM-BASED AD

The process of evaluating an AD for a dairy farm is best initiated by having a feasibility study performed by a qualified third-party team of professionals, including a lead engineer, economist and financial expert along with the farm's financial consultant. The goal of a feasibility study is to provide factual-based information that can be used to determine if the goals and objectives of the farm can be met by the installation of a digester, or not. In essence, the completed feasibility is a tool for the farmer to use in making a prudent business decision.

Experience has shown that many farmers also benefit from assistance provided in determining and prioritizing the goals and objectives for their farm with regards to manure treatment, nutrient management, and energy use and generation potential.

The results of a farm energy audit are always beneficial to the engineer performing the feasibility study. An energy audit will provide monthly electrical energy usage along with energy used for heating purposes. This information is used to determine if sufficient heat and power is available from the proposed AD system to operate the farm continuously or only partially.

Farms must carefully consider the economic implications of investing in an AD system before they begin construction. ADs in the U.S. vary in capital cost depending on factors such as the size, design, materials used, equipment and complexity of the system, but in general the current range seems to be $1,000 to $1,200 per cow and in some cases is more. This is in the same general price range as a new freestall housing barn. A qualified economist can use information provided by the feasibility study results to make cash flow projections and calculate the projected return on investment prior to making a final decision on building a digester or not.

APPENDIX 6. SUMMARY LESSONS LEARNED AS REPORTED BY VARIOUS NY AD OWNER/OPERATORS

Most digester owners/operators in NY have reported their positive and negative experiences from the project and important lessons they have learned in different venues. A compilation of common problems, successes and overall lessons learned as communicated by digester operators are shown below by category. ‘The farm’ mentioned in the statements below, refers to the digester operator(s) providing that specific comment, and represents several digester operators throughout the table. All observations expressed here originated from NY digester operators. These comments are provided for the benefit of future digester owners/operators to prevent similar problems and to encourage strategies that were found to be successful.

Economics
“The price the farm receives for electricity sold back to the utility grid needs to be much higher in order to make the digester system financially viable.”
“The projected savings from hot water use never materialized, since changing from the existing radiant heating system to a hot water heating system in the milking center would have been cost prohibitive. Since electricity produced by on-farm generation can meet the electric needs of the farm, there was not a significant incentive to make an expensive change.”
“The cost estimate for the farm’s AD project was initially less than $500,000. The actual cost to date has been over $1,300,000. It is important to get realistic cost estimates and include plans for contingencies.”
“The farm has experienced that accepting food waste can substantially offset the cost to own and operate the digester. The tipping fee received is $0.06 per gallon for whey delivered to the farm by the processor. A profit center approach to the manure treatment system justifies the management requirement for the digester operation. This additional income should also help to offset the estimated $700,000 in equipment maintenance and replacement the farm expects.”

Digester Design
“Choosing an engineering company to design and construct the digester was confusing. Each company had different ideas of the type of digester: gas collection, gas cleaning, electrical generation system, electric hook-up and heating system. Each company had to have the capacity, tenacity and range of expertise to put a complex system together on the farm. Comparing companies with different pricing schemes, sales pitches and promises was difficult. Many seemingly insignificant issues became serious issues when they caused the whole system to fail. The farm believes it is important to review the experiences and references of the engineers carefully, paying particular attention to their work on similar projects.”
“Difficulties were encountered when there was a disconnection among the design team. Different areas of the company were unaware of aspects of the project out of their scope of responsibility, and the farm received very different recommendations and opinions from people in the same area of expertise.”
“Engineering companies must combine several disciplines in order to design an AD system. Drains to control the water table around the digester to prevent buoyancy of the empty digester and to control heat loss were not included in the initial designs. Uplifting and excessive cooling were prevented by adding well-positioned drainage pipes after construction. The farm learned that all in-ground structures should have drainage systems in the backfill to reduce heat loss and to prevent flotation.”
“The anaerobic digester system should have been completely designed and laid out prior to starting construction. Engineering design was an ongoing process that resulted in construction delays that could have been avoided.”

"The digester is a complex system that required more time to design and build than many other components of the farm, including barns, parlors and long-term storages. Design of the system required several months and construction lasted more than a year. The farm believes that producers need to understand and plan for the time required before they start the process of installing a digester on their farm."
"The anaerobic digester — including manure handling, gas collection, gas utilization and digester heating, should be designed as a system. This site experienced a structural beam failure due to lateral loads that were not anticipated. If the concrete design had been better integrated with the rest of the system, this problem may have been avoided."
"The farm experienced that all digester system components need to be properly sized, constructed, installed, operated and maintained properly in order for the system to operate effectively and efficiently."
"The farm believes that a complete mix digester should have been chosen in lieu of a plug-flow digester. Formation of a crust within the digester has caused problems. It is believed that the addition of restaurant grease-trap waste will help reduce crust build up; the farm adds about 10 gallons per day. On occasion, the farm also adds similar volumes of a byproduct from a biodiesel plant."
"Two parallel cell digesters were constructed to avoid one excessively long digester. Additionally, the twin digester design makes it possible to shut down and start up each digester independently and therefore increases management flexibility. Operating experience has shown that it is hard to divide digester influent equally between the two digesters; an appropriately designed flow meter along with an automated control device may help solve this problem."
"The microturbine and control room were located closer to the existing electrical infrastructure as opposed to locating it closer to the AD. Heating pipe was installed a long distance instead of electric conductors. Because of this, hot water must be pumped across the farm to heat the digester, and significant heat and energy is wasted in the transport process. Better operation and energy efficiency could be achieved if the digester and its power generation equipment had been located closer to each other."
"The farm has experienced that heavy snow load can collapse the flexible cover on the digester if it accumulates faster than it can melt. Shoveling the snow off will allow the cover to re-inflate."
"When foaming occurs, the biogas collection and transport pipes often fill with foam. The digester biogas pressure-control system consists of water buckets that maintain the proper water level to sustain biogas pressure. Providing a drain for the pipe chases, a solid bottom and water supply, has made clean-up easier. Removing the top of the pipe chase allows easy access and good ventilation for those working in the area. The manure influent pipe should not have been located in the same pipe chase as the pipe carrying biogas from the digester."
"Temperature sensors installed in vessel read 3°F higher than reality. Checking and calibrating the instrumentation should have been an important step in start-up procedures."
"The weir wall consists of wooden boards placed across the concrete opening at the outlet of the digester. These wooden boards eventually failed. Until repairs were made, it was necessary to keep the effluent pit full in order to prevent the loss of biogas."

Solid/Liquid Handling
"The flow gutter often becomes clogged with solids and must be flushed with milking center wash water. The problem is acquiring clean water to flush with, since the wash water from the foot baths contains copper sulfate, which the farm believes decreases microbial activity in the digester."
"The farm experienced that changing the feedstock of the digester too quickly can disrupt the normal functioning of the bacteria and shock the system."
"The plug-flow digester on our farm relies on the proper moisture content of the influent. It was observed that when extra liquid is added to the influent, the floatable and settle-able solids

separate inside the digester leaving a floating crust and a settled deposit. The farm believes that as these two portions of the digester get larger they will decrease the useable volume in the digester and decrease the hydraulic retention time. We foresee that lower retention times will decrease biogas production and fail to reduce the odors in the effluent."
"Before the AD system was constructed, a feasibility study was performed to explore the possibility of partnering with other nearby farms to construct a community-based anaerobic digester. A major disadvantage discovered was the expense of manure transportation to the community site and the expense of transporting digester effluent back to each farm."
"Subsequent to digester commissioning, it was determined that the food waste (cheese whey) storage pits needed to be covered in order to minimize odor emissions."
"Co-digestion with food waste contributes additional solids to the digestion system, and the farm observes that the effluent has a lower solids content than if manure were digested alone. The farm interprets this to mean the extra energy content of food waste apparently makes it possible for additional solids destruction."
"The food waste received by the farm is high in energy, having almost three times more biogas production per unit of mass than manure. However, not all farms can take advantage of this. The farm believes that only farms that have a land base able to accept extra nutrients should consider this option."
"Accepting food waste is highly profitable for the farm – tipping fees make the manure treatment system a profit center for the farm. This is a win-win situation for the farm and the food processor. The company supplying food waste has an environmentally responsible and relatively less expensive way to export their waste product(s). Nutrients from the food waste are recycled back to the land and power is produced from a renewable source."
"The farm believes that solids are destroyed in the long-term storage when post-digested manure is introduced. The existing manure storage was approximately one-half full of manure solids when digested effluent was introduced. After two years of operation, the farm observed that the solids in the storage had decreased significantly without excessive agitation."
"When digester effluent was added to the heifer barn's manure storage pond, the farm observed that odor was reduced. The farm deduced that, to control on-farm odors, not all manure has to be digested, and that mixing digester effluent with raw manure may provide some odor control."
"Post-digested separated manure solids were used as bedding for a short time. Incidence of mastitis increased in the milking herd and bedding was the first potential cause that was eliminated. The farm decided the use of manure solids for bedding was too much of a risk for the health of the milking herd."
"Compost marketing needs to be done in order to sell post-digested separated manure solids. The separated, digested solids are homogeneous, dark in color, and have good tilth. When the digester was constructed, the demand for compost or manure solids was not evident, and transportation costs restricted the potential marketing area to relatively near the farm. Currently however, more interest is being generated in the use of separated manure solids, and if a stable and reliable market can be found, the revenue collected from this byproduct would be a valuable asset in the economic performance of the digester."
"Sale of post-digested separated solids cured and marketed as compost, has been increasingly successful over time due to repeat customers, word-of-mouth advertising and the use of a Web site. Compost prices vary depending on the size of the purchase. All post-digested solids turned into compost are able to be sold."

Biogas
"The farm feels that the sizing of the gas handling system needs to account for the additional production of biogas that food waste creates. Pre-planning and analysis of possible food waste sources was helpful to the farm to estimate gas production potential."
"The farm experienced that raw biogas was released by the top cover due to seal imperfections

and the biogas pressure relief system. Biogas release events resulted in odor emissions that were more offensive than untreated manure stored long-term. This has presented an issue with on-farm odor that is now worse than prior to digester construction.”
“The digester was designed with a hard top with the goal of developing 12 inches of water column biogas pressure to force biogas into the compressor. The compressor is needed to increase the biogas pressure to a microturbine target inlet pressure of 90 psi. Difficulties were encountered in sealing the concrete top which led to biogas leaks and partially digested byproducts. Biogas leaks caused odor problems, and since the equipment building was initially located on top of the digester, leaking biogas created both a safety problem and a corrosive environment for electronic equipment.”
“The initial design was to maintain pressure within the digester at 6” of water column. However, it was found that the flare would not function properly at this pressure, thus, the decision was made to increase the pressure to 10” of water column. Since this change has been made, excess biogas has been successfully flared, and emissions of raw biogas have been eliminated.”
“A blower and control system was installed in an attempt to keep the biogas pressure in the digester head space neutral to minimize biogas leakage; however, when the equipment fails, biogas still leaks, causing odor emissions. The farm experienced that the greater the pressure the more difficult it was to seal the digester. The farm feels that digesters operated at high pressures should be pressure-tested as part of the start-up procedure. Use proven technologies to seal digesters.”
“Conditioning biogas before sending to the compressors and microturbine is critical for the power generation system. Hydrogen sulfide and water vapor in biogas present the potential for corrosion — the compressor has sensitive components that will corrode. A biogas scrubber, with iron-coated bark as the operative cleaning device was installed to remove hydrogen sulfide.”
“When biogas was not being combusted by the engine, a blow out in the pipe chase would occur, since the diameter of the pipe carrying excess gas to the flare was too small. Keeping the gravity flare lit during windy conditions for high and low biogas flows was difficult. Two automatic spark ignition systems are needed in this case to provide a spark where a flammable mixture of biogas and oxygen is present. The decision was made to change to a power flare, due to the windy conditions and highly variable biogas flows.”
“The farm believes it is important to separate equipment from biogas sources.”

Power Generation
“A complete engine-generator set and biogas handling skid, appropriately sized and assembled in a factory, provided ease of design and mechanical equipment installation. The system was assembled with compatible equipment and controls so on-farm installation was easily accomplished.”
“The engine-generator set was selected by the farm based primarily on price and not the most efficient size. A used engine-generator set became available and was purchased for use in the digester power generation system. This oversized engine is less efficient in converting fuel to power at lower operating speeds.”
“Since the digester was designed for 1,000 cows and is operating it at half capacity, it has reduced process efficiency.”
“The farm believes that two smaller engine-generator sets should have been chosen instead of one larger unit. Some of the engine-generator set maintenance requires downtime and consequently results in the need to procure power from the local utility, which increases the farm’s standby demand charge.”
“Burying the engine-generator set exhaust pipe and out-letting it some distance from the engine room helped to reduce corrosion of the biogas utilization building and also helped to reduce

noise near the building. The internal combustion engine is loud. Additional sound control may further reduce noise emissions.”
“The noise from the engine in an un-insulated pole barn is loud. People that had been keeping their windows shut from the odor were beginning to complain about the sound. Providing a sound insulated engine room can reduce the sound on-farm as well as the sound heard from a distance.”
“The microturbine is sensitive to biogas pressure and methane concentration, which can vary widely. The microturbine has complex, sensitive electronics controlling its operation; however, it had significant advantages over an internal combustion engine (including energy conversion efficiency, lower maintenance need, higher exhaust temperatures and less noise) based on the goals of the farm.”
“The majority of the problems experienced in the past with microturbines on the farm were due to the corrosive environment created by the leaking concrete top. The electronics had to be replaced after being in a corrosive gas environment prior to start-up. Also, the initial biogas compressors failed despite specifications for biogas use.”

Heat
“Operational experience revealed that the digester heating system had several initial design flaws. The heat exchanger was sized too small to heat digester influent to 100°F. In addition, groundwater saturating the insulation outside the digester increased heat loss.”
“The heat balance of the digester system is vital. The design needs to address heat recovery from the engine, methods to heat the AD influent, and correct estimates for maintenance heat, which is needed to maintain a constant temperature in all weather conditions.”
“Maintaining control of digester operating temperature is important, especially during cold weather. Frozen manure and manure with excessive water regularly bypasses the digester. When the digester feed is reduced, biogas production decreases and less heat is available to warm influent. In this case, either external energy is needed to maintain the digester operating temperature, or the digester needs several months of warmer weather to recover.”
“Temperature control of the digester is critical for the AD system. Air locks in the heat pipes can prevent proper circulation of hot water inside the digester to heat the incoming manure to 100°F and to keep it at operating temperature throughout the 20-day retention time. It is imperative that temperature gauges are calibrated and working properly, to help diagnose a possible heat-loss problem.”
“The farm believes that groundwater impingement on the bottom of the digester can significantly reduce the temperature of hot water piped to the digester to maintain operating temperature. When a reduced volume of material is transferred to the digester, the amount of heat to the digester is adjusted, since heat will not be needed for incoming manure. Without adjustment, higher temperatures than desired may result.”
“There is a significant amount of heat recovered from the engine-generator set, which is used to heat the digester influent, to maintain the digester operating temperature, and to heat the calf barn and milking parlor. Despite the many uses for waste heat in our system, a radiator to dissipate extra heat is still needed. The un-insulated gas utilization building is kept very warm, even in the winter months, due to the excess heat produced by the engine. This offers a prime opportunity for a shop facility.”
“Although heat recovered from the engine-generator set can be supplied continuously for on-farm demands during sharp cold snaps, in-floor heating was not sufficient to prevent the pipes from freezing.”

Other
“The farm experienced that a project with comparatively high capital cost requires a dedicated person to research the funding opportunities, construction specifics and permitting requirements

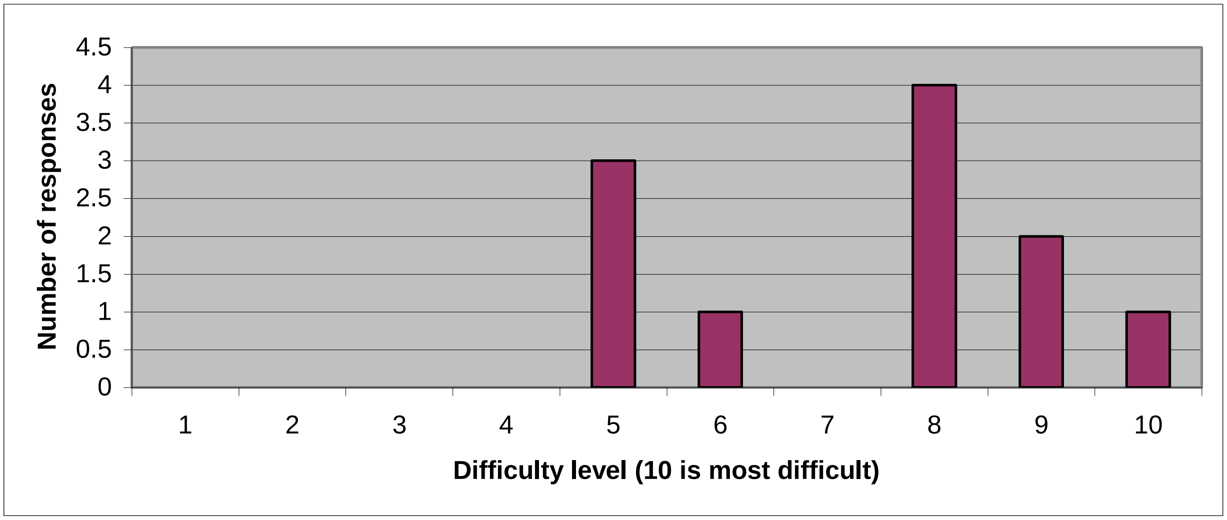
prior to construction.”
“One difficulty noted by the farm during the construction process, was the repeated delay and mistakes in ordering of parts and materials. This issue lies more with the companies providing supplies, but the farm should be cognizant to choose reliable companies to furnish parts.”
“The farm invested in various pieces of equipment considered “extra” for the AD system, including a biogas conditioner, draghose and SLS separator, in order to reduce future farm maintenance needs for the system and assist in the overall goal of recycling manure from the barn to the field, with as little effect possible on humans and the environment.”
“Utilizing farm labor to construct the digester was a cost-savings method, which required the farm to be intricately involved in bringing together several components of the AD system. This involvement was valuable in the long run for maintenance and troubleshooting of future problems with the AD system.”
“Currently there are no entities that provide complete technical support or services for anaerobic digestion systems. There are several separate digester components designed by different companies that need to come together for successful digester operation and biogas utilization.”
“Technical service support was found to be lacking for much of the equipment associated with the digester system, including the engine-generator set and electrical connections. A small problem that went unfixed for a long period of time led to a more serious problem. There is demand for maintenance service to assist farms in operating and maintaining digester system components.”
“Anaerobic digestion systems have associated safety requirements that are new to a production farm that have taken time and investigation to fully understand.”
“Foaming has occurred when operational and management changes were made, such as changing the diet of the cows, changing the temperature of the digester or adding other organic materials. Foam escaping from the digester creates a mess, but spraying the foam with water seems to control the foaming. A water source and spray device near the effluent tank has proven to be useful.”
“Shock-loading a digester with high-energy food waste has been known to create substantial amounts of foam. Loading the digester incrementally has reduced the incidence of foaming.”
“Manure-associated odors have shown to be negligible when the volatile acid levels in the AD effluent are below 500 ppm. Changes in temperature control or retention time have shown to affect the volatile acid concentration in digester effluent, resulting in a potential increase in odor emissions.”

APPENDIX 7. PRODUCER PERSPECTIVE SURVEY

Survey #1: AD Operator Survey

Question 1. On a scale of 1-10 (1 being easiest and 10 being hardest), please rate the ease of installing an AD on your farm.

Response 1:



Question 2. Did you experience any major setbacks on the construction and installation of your AD (yes/no)?

Response 2:

	No. of responses
Yes	9
No	2

Question 3. Please choose which categories below concern the issue(s) you encountered during the installation of your AD, and give a brief description to the right: design, construction, interconnection, regulations, start-up phase, other.

Response 3:

Category	*No. of responses indicating issues were experienced*	*Comments (number of incidences)*
A. Design	7	• No written plan (1) • Poor design (1) • Issues with finding appropriate equipment that had a performance guarantee • Difficult to determine designer's qualifications • Difficulties in obtaining appropriate instrumentation for gen-set • Issues with keeping the flare lit • No method to bypass parlor water from digester was designed into system; difficult to change afterwards
B. Construction	6	• No written plan/poor planning (2) • More management needed (1) • Design standards must be met at a reasonable price and with a quality contractor (2) • On-site engine assembly is complex
C. Interconnection	9	• Utility interface (3) • Expensive (2) • Time-consuming (4) • Confusing (2)
D. Regulations	5	• All regulations are not known • Regulations change constantly • Regulations can affect design • Maximum electricity generation limits • DEC engine emission issues
E. Start-up phase	3	• Slow (1) • Costly (1) • No standard operating procedures for equipment (1) • Trouble sealing gas leaks (1) • Consistency of manure as a start-up dairy
F. Other	2	• Compliance with grant regulations (2) • Overall project financing (1)

Question 4. How could the above problems have been prevented (for example, regulatory changes)?

Response 4:

Suggested change	*No. of incidences*
Have a complete design, drawings and specifications	5
Have/utilize third-party advice (need more resources and support)	2
Having qualified construction management team	1
Have a clear interconnection process and requirements	2
Increase net-metering limits	1

Question 5. Do you perceive that other producers have a difficult time installing an AD system (yes/no)?

Response 5:

	No. of responses
Yes	11
No	1

A comment from the responses to Question 4: "Depends on management style – you have to be willing to spend a bit more money upfront to prevent challenges later – we feel other producers will probably make shortcuts to cut on costs and this will make it more difficult in the long run."

Question 6. What do you hear are the major barriers to adoption of digester technology?

Response 6:

Barriers	*No. of incidences*
Perceived design intellectual property issues affecting: management, cost and construction timetable	1
Milk price volatility	1
More attractive investments	1
Capital cost	4
Value of green power sale	2
Complexity of design	1
Utility issues	5
Attractive alternative to power sale	1
Dedicated management by the farm	3
Manure handling	1
Obtaining grant funding	1

Question 7. In order of importance, please list below the top **three** issues that you believe need to be addressed/changed in order to ease the installation of digesters in NY.

Response 7:

Priority ranking	*Response*	*No. of incidences*
1	Standardized AD design	1
1	Milk price volatility	1
1	Reduce capital costs	2
1	Interconnection requirements	2
1	Decrease grant complexity	2
1	Increase grant availability	2
1	Farm must be dedicated to a successful AD	2
1	Return on investment	1
1	Operation complexity	3
1	Turnkey system design	1
2	Technical support/service industry needed	2
2	Regulations	1
2	Green power value	2
2	Update grid infrastructure	1
2	Interconnection requirements	2
2	Financing the system	1
3	Advertise success of existing systems	1
3	Utility issues	2
3	More value for green energy	1
3	Alternative biogas uses	1
3	Standardized design and equipment	1

Survey #2: Producer Without On-farm AD System Survey

Question 1. Have you considered installing an AD on your farm (yes/no)? When?

Response 1:

	No. of responses	*Date when considered*
Yes	14	• Within the next 5 years • Mid-2008 • 5 years ago • 2003 – 2007 • Within 2 to 3 years • Within next 1 year • 2007 • 2006
No	7	

Question 2. Is there a reason(s) that has kept you from proceeding with installation? If so, please describe.

Response 2:

Barriers	*No. of incidences*
Sand bedding	6
Capital costs	14
Net metering issues	3
Poor investment	9
Design/complexity	3
Track record	2
Farm size (too small)	2
Management/farm effort needed to operate	4
Lack of long-term power purchase agreements	2
Lack of technical support/service	1
Utility issues	2
Manure handling	2
More attractive investment opportunities	2
Milk price volatility	1

Question 3. Do you hear from other producers that installing an AD is a difficult process? If so, what do they cite as the issues?

Response 3:

	No. of responses	*Barriers cited (No. of incidences)*
Yes	15	• Extra labor required to operate (3) • Lack of support from AD companies (3) • Permitting (1) • Securing grants (3) • Low value for excess electricity (1) • Difficulties with interconnection (1) • Time/effort pre-operation stage (3) • Local contractors are not always familiar with necessary protocols for AD construction (1) • Costs (4) • Operation/maintenance challenges (3) • Too many unknowns (1)
No	2	

Question 4. Please choose from the list below any options you believe are barriers to installing digesters on farms in NY: regulations/permitting, perceived shortcomings of existing systems, lack of qualified operators, lack of qualified service providers, high capital costs, neighbor relations/community perception, pathogen concerns, other.

Response 4:

Category	*No. of responses indicating issues were experienced*	*Comments*
A. Regulations/permitting	7	• This is a strong concern • Grant requirements
B. Perceived shortcomings of existing systems	16	• No post-sale support exists • Farmstead odor increases • Sand-laden dairy manure (SLDM)
C. Lack of qualified operators	14	
D. Lack of qualified service providers	10	• Need local service support
E. High capital costs	19	• Can offset costs with a partner • Design shortcomings create extra costs
F. Neighbor relations/community perception	3	N/A
G. Pathogen concerns	2	N/A
H. Utility interconnection	15	• Costly process • Capacity limits
I. Other	3	• Extra labor required • Air emission issues • Lack of long-term power purchase agreements

Question 5. What is the most major issue that needs to be addressed/changed in order to ease the process of installing an AD in NY?

Response 5:

Barriers	*No. of incidences*
More user-friendly system	3
Reliability of current AD designs	1
Capital cost reduction	7
Government "support" (e.g. grants, legislation changes, etc.)	1
Not sure	1
Net-metering (allow multiple meters)	1
Higher payment for green power	5
Remove milk price volatilization	1
More attractive return on investment	3
More grant availability	2
AD design for SLDM	1

APPENDIX 8. SURVEY REVIEW, "NORTH COUNTRY NY DAIRY FARMER VIEWS ON ALTERNATIVE ENERGY PRODUCTION"

In 2008, several surveys were sent to producers across the state by a team from Clarkson and Cornell Universities to determine a) the level of knowledge of anaerobic digestion, and b) perceptions of anaerobic digestion for dairy farms. The results were published in a paper (Gremelspacher et al., undated), North Country NY Dairy Farmer Views on Alternative Energy Production. The main difference between the North Country survey and the results from the surveys conducted by Cornell: Survey #1 and Survey #2 presented previously in this chapter, is that the latter surveys were targeted toward larger farms, arguably more likely to implement AD technology, whereas, the following survey results are mostly from smaller farms across the state.

The survey results presented in North Country NY Dairy Farmer Views on Alternative Energy Production targeted dairy farmers in the North Country region of NY, and incorporates responses from 418 farmers of varying farm sizes. The extent of farmers' knowledge of AD was through reading popular press articles, which 91% of farmers surveyed said they had done. Only 13% had taken further actions to attend a meeting to learn more about the technology.

Farmers were asked to rate which benefits they associated with AD. The two highest responses were: producers thought that "providing electricity for use on-farm" was a benefit (88% of producers), and farmers thought that "reduced odor from manure" was a benefit (75% of producers). When asked about bedding type, only 16% responded that use sand bedding, the majority, 48% and 17% use, respectively, hay and sawdust.

In terms of concerns that producers have with on-farm AD, 87% said that digesters are very expensive to install, 31% said necessary technical expertise is unavailable, and 30% said they require a lot of labor and time to operate. 53% of farmers surveyed were interested in getting heat and power for on-farm use from a digester on their farm, and 46% were interested in having excess electrical or fuel energy for sale to utilities or other customers.

When asked to agree or disagree with the statement, "Digesters would be viable options for most dairy farms in NY" 31% disagreed, while only 12% agreed; 44% were not sure. When asked to agree or disagree with the statement, "Digestion technology seems too capital-intensive to make sense for my operation" 45% agreed and 29% strongly agreed. When asked to agree or disagree with the statement, "Digestion technology seems too mechanically complex for everyday operation on my farm" 37% agreed while 35% were not sure.

Appendix 8 Reference:

Gremelspacher, M., G.G., R.W. Undated. North Country NY Dairy Farmer Views on Alternative Energy Production.

APPENDIX 9. RPS PERFORMANCE REPORT

The current target installed capacity (MW) for anaerobic digester biogas projects under the Customer-sited Tier (CST) program is 8.8 MW by December 31, 2009. To achieve this goal, the Anaerobic Digester Gas-to-Electricity (ADG) program, which began in August 2007, has made $20.1 million dollars available to new ADG projects in the form of a performance-based incentive payment (maximum $1 million per ADG system). It is recognized that there is an increasing rate of new ADG projects in New York, and to keep pace with this demand, additional funding under the RPS CST Program will be needed (NYSERDA, 2008).

The overall RPS targets for each RPS program are shown in Table 10. The 24 applications received at that time (2009) for new ADG projects (total of 7.3 MW in applied projects) not only met the then-target capacity (3.7 MW) for this resource, but nearly doubled the expected target. The expected progress toward the original 12/31/2009 target is 237% for anaerobic digester biogas projects, the second highest after solar photovoltaic which was due to federal tax incentives that highly stimulated the market (NYSERDA, 2009).

Table 10. NY RPS Energy Targets (MWh) (NYSERDA, 2004)

	Main Tier Targets	Customer Sited Tier Targets	EO 111 Targets	Voluntary Market Targets	Combined Targets
2006	1,121,247	25,259	282,812	228,584	1,657,902
2007	2,326,171	50,488	314,579	457,167	3,148,405
2008	3,549,026	75,685	346,366	685,751	4,656,828
2009	4,767,994	100,855	378,174	914,335	6,161,358
2010	6,012,179	125,988	410,002	1,142,919	7,691,088
2011	7,297,746	151,081	391,857	1,371,502	9,212,186
2012	8,556,710	176,123	373,712	1,600,086	10,706,631
2013	9,854,038	201,130	355,568	1,828,670	12,239,406

As of March 2009, the Main Tier had 1,164.1 MW of new installed renewable energy project capacity under the RPS program, and the Customer-sited Tier had 2.14 MW installed, 6.37 MW under contract, 13.89 MW in pending contracts, and 3.87 MW projected capacity.

“Because of the success of the RPS program, New York has become a national leader in the development of new renewable energy capacity (NYS PSC, 2009).”

Appendix 9 References:

NYS PSC. 2009. 03-E-0188: NY RPS Proceeding Home Page. Web address accessed 9/2009: http://www.dps.state.ny.us/03e0188.htm

NYSERDA. 2004. Renewable Portfolio Standard Further Reading. Web address accessed 9/2009: http://www.nyserda.org/rps/furtherreading.asp#history

NYSERDA. 2008. New York State Renewable Portfolio Standard Performance Report (June 2008).

NYSERDA. March 2009. New York State Renewable Portfolio Standard Performance Report (March 2009) http://www.nyserda.org/rps/RPSPerformanceReportwebnew.pdf

APPENDIX 10. NY ENERGY PLAN ADDITIONAL REVIEW

Energy Infrastructure Issue Brief
The following information is summarized from the Energy Infrastructure Issue Brief document, which can be found in the 2009 NYSEP.

There are three major entities in NY that share responsibility to regulate electricity transmission:

- New York Independent System Operator (NYISO)
- Public Service Commission (PSC)
- Federal Energy Regulatory Commission (FERC)

Uncertainty with regard to the authorization process for interconnecting electricity generation to the state's power grid is a major issue for AD operators wishing to sell excess power back to the grid. The PSC has addressed interconnection misunderstandings by releasing the Standardized Interconnection Requirements for Distributed Generation document (http://www.dps.state.ny.us/Final_SIR_02-12-09_Clean.pdf), which addresses farm waste digester systems. This document mandates to each of the utilities and distributed generators the required process for interconnecting AD systems, as well as other renewable systems, to the grid for sale of excess power back to the utility. The NYSEP states that NY has a major interest in resolving the delays in the interconnection process for all resources, especially with regard to renewable resources. More than 8,000 MW worth of renewable projects are in the NYISO queue, representing generation that can help meet NY's RPS program goal. An additional issue with interconnection, which the issue brief mentions but does not address, is that there is no information to suggest what upgrades (to the grid network) are reasonable to have the rate payers or the state cover. More information regarding current issues surrounding the issue of interconnection costs can be found in Chapter 4.

Smart Grid technologies being investigated by the utility companies have the ability to increase efficiency of power distribution, thereby reducing cost and environmental impacts. The Issue Brief, as well as the Electricity Resource Assessment, both contain a substantial discussion of the need to replace and update aging electricity infrastructure. The NYISO is performing a Congestion Assessment and Resource Integration Study (CARIS), and "bottled generation" studies are under way by the utilities to find the areas with the heaviest transmission congestion.

The NYSEP indicates that additional natural gas pipeline capacity is needed, especially for the downstate region, which suffers from constrained pipeline capacity. A new interstate pipeline has the potential to increase the diversity of gas supply to the region. It is important to note that AD projects could be positioned to connect to the new gas pipelines and directly inject cleaned, scrubbed and compressed biomethane.

Climate Change Brief

The following information is summarized from the Climate Change Brief document, which can be found in the 2009 NYSEP.

From the beginning, the Climate Change Brief mentions what a huge challenge it is to transition to an energy system with significantly reduced GHG emissions. The International Panel on Climate Change (IPCC) has set a goal of ‘80 by 50,’ meaning that GHG emissions must be decreased to 80% below the level they were in 1990, by 2050. President Obama and the U.S. House of Representatives have supported a national plan to cut back emissions to 83% below 2005 levels, by 2050. NY plans to develop a Climate Action Plan to determine how to best meet the goal of ‘80 by 50.’ In terms of climate-changing effects on agriculture and tourism, the Climate Change Brief notes that dairy farmers may be severely affected due to the expected warming of the area’s climate, since milk production is enhanced by cooler climates. The brief continues to discuss that a loss of milk production efficiency from heat effects could result in the loss of millions of dollars annually for NY’s dairy industry. However, in 2007, 6.5% of the total CO_2e emissions in NY came from methane (15.5% of that portion was agriculturally derived), thus, the NY dairy industry also has opportunities to assist in reducing the impact of GHG emissions. New high-voltage lines (both high-voltage transmission and low-voltage local distribution lines) would encourage renewable energy, in this case from AD biogas-derived electricity, to be supplied to the grid.

Appendix 10 Reference:

NYSEP (draft version) 2009. Web address accessed August 12, 2009:
http://www.nysenergyplan.com/stateenergyplan.html

APPENDIX 11. PSC ROLE FOR DISTRIBUTED ENERGY GENERATION SYSTEMS

In order to develop uniform interconnection requirements across all NY utility companies, the PSC developed the SIR guidelines. This is an important document for producers to review and understand before beginning the process of installing an AD system to generate power. A summary of the guidelines presented in the SIR document are outlined below:

Step 1: The applicant initiates communication with the appropriate utility company.

Step 2: The utility company performs an initial review of the project, and a representative is assigned to the project to be the point contact person.

Step 3: The application for interconnection is submitted by the applicant; this application must include a completed standard application form.

Each utility must provide a Web-based system for applicants to see the status and progress of the SIR application.

Step 4: The utility company performs a review of the application and develops a cost estimate for the Coordinated Electric System Interconnection Review (CESIR).

- The utility will inform the applicant as to whether they believe the project to be feasible.
- The utility will provide the applicant with an estimate of costs to complete the CESIR.
- This review and the estimates should be provided to the applicant within 15 days.

Step 5: The applicant approves and commits to the CESIR.

Step 6: The utility company performs the CESIR to determine whether the generation project will disrupt the grid in any way or present any safety concerns for other customers on the line.

A full CESIR may not be necessary if the generation is less than 150 kW on a single distribution feeder line. The CESIR must be completed within 60 business days of the information being provided by the applicant in Step 5.

After the CESIR is completed, the utility will inform the applicant of any issues the project presents for interconnection to the grid and whether the system meets all regulation criteria.
In terms of the cost estimates for utility upgrades associated with the project:

1. If the applicant will be net metered, the applicant does not have the responsibility to pay costs associated with any required modifications to the utility system, administration, metering and on-site verification testing, and the utility must provide a statement showing the applicant’s cost to install any dedicated transformer(s) and other safety equipment.

2. If the utility determines a dedicated transformer(s) or other safety equipment must be installed, a farm waste customer-generator up to 500 kW capacity has a maximum equipment responsibility of $5,000.

Step 7: The applicant commits to construction of the utility's system modifications.

Step 8: Project construction

- The generation facility will be constructed following the design plan being accepted by the utility company.
- The utility company will install at this time any equipment on-site that is determined in Step 6 to be needed for net metering of the system.

Step 9: The applicant's facility is tested in accordance with the SIR.

- This testing step will occur 10 business days within the commissioning of the project.

Step 10: Interconnection

- The applicant may begin operations.

Step 11: Utility cost reconciliation

APPENDIX 12. NY UTILITY TARIFF REVIEWS

It is a common response from producers with and without digesters operating on-farm, that utility interconnection is believed to be one of the most arduous tasks of installing a digester. The main issue, as understood through interactions with the utilities, is a simple one — farms are located in rural areas usually at the end of distribution lines where the electric grid ends in a series of small feeder lines, not designed or able to handle the large amounts of power farm AD generators wish to put back on the grid (NYSEG, 2009).

Utility companies in NY have shown to have a large impact on the interconnection process that allows AD to act as distributed generation facilities. Of the several utility companies in NY, three were chosen to detail their positions on renewable energy and farm waste net-metering. The three utilities that exist in the areas most densely populated with dairy farms are: New York State Electric and Gas Corporation (NYSEG), Niagara Mohawk Power Corporation (d/b/a National Grid), and Rochester Gas and Electric (RG&E). A brief overview of each utility's regulations regarding distributed generation is provided below.

New York State Electric and Gas Corporation (NYSEG)

Many of the regulations in the NYSEG tariff mirror those in the Net Metering law and Standardized Interconnection Requirements (SIR), and tariff indicates that customer-generators must refer to the PSC SIR guidelines.

The following requirements must be met for any customer wishing to participate in the Farm Waste Electric Generating System Option to become a net-metered customer under NYSEG jurisdiction:

- The rated capacity of the farm waste generator cannot exceed 500 kW
- Power must be generated by a minimum of 90% biogas produced from AD, on an annual basis.
- The digester feedstock must be 50% by weight livestock manure.
- Power can be sold back to the grid on a first-come first-served basis, until the quota of power generated from solar and farm waste generation systems combined is reached, which is 28,260 kW, equal to 1% of NYSEG's electric demand in the year 2005.
- NYSEG will install appropriate metering devices for a net-metered customer: even if a second meter is determined to be needed, NYSEG will pay for it. If NYSEG determines it is necessary to install a transformer to protect the grid and other customers from power disturbances by the customer-generator delivering power back to the grid, the customer will be responsible for paying NYSEG's costs of purchase and installation for the necessary equipment, up to $5,000 per farm operation.
- For time-differentiated rates (TOU meter), if NYSEG provides more electricity to the customer-generator than the customer-generator delivers back to the grid, then NYSEG will bill the customer for the net kWh supplied by NYSEG during that billing period. This "netting" of kWh will occur each billing period.

- For time-differentiated rates (TOU meter), if the customer-generator delivers more electricity to the grid than NYSEG provides to that same customer-generator in a billing period, then a kWh credit will be carried forward for the next billing period.

- For demand-billed customers, excess kWh the customer-generator delivers to the grid are converted to a dollar value and applied as a credit to the current bill. Any excess dollars remaining will be converted back to kWh and carried forward to the next billing period as a kWh credit.

- If the excess kWhs in each of the scenarios above are a positive balance at the end of a year, NYSEG will give a cash payment to the customer-generator for the amount of excess kWh times the average avoided cost for energy of the 12-month period.

- Regarding electric hybrid generating systems, any customer who owns/operates two types of electric generation systems (for example, a farm operates an AD system on their farm and generates electricity, but also wishes to install a small wind turbine to produce electricity as well), an option is available to allow hybrid facilities to have the benefit of net metering. All customers desiring to operate a hybrid facility must comply with the PSC SIR guidelines.

National Grid

As is the case with the NYSEG tariff, the National Grid tariff contains many of the same regulations as the Net Metering law and the PSC SIR guidelines, and the tariff mentions that customer-generators must refer to the PSC SIR guidelines.

The following requirements must be met for any customer wishing to participate in Net Metering for Farm Waste Electric Generating Systems under National Grid jurisdiction:

- The rated capacity of the farm waste generator cannot exceed 500 kW.

- Power must be generated by a minimum of 90% biogas produced from AD, on an annual basis.

- The digester feedstock must be 50% by weight livestock manure.

- Power can be put back on the grid on a first-come first-served basis, until the quota of power generated from solar and farm waste generation systems is reached, which is 65,360 kW, equal to 1% of National Grid's electric demand in the year 2005.

- If National Grid determines that an additional meter(s) is necessary for allowing net metering of the system, it will pay the cost of the necessary meter(s). However, customer-generators cannot offset utility bills at other meter locations — only the single meter delivery point. The net energy billing procedures for National Grid are as follows:

    - If the electric energy supplied by National Grid is greater than the amount of electrical energy supplied by the customer-generator during a billing period, then National Grid will charge the customer the rates provided in the appropriate retail rate schedule for only the difference between the two amounts.

  - If the electric energy sent back to the grid by the customer-generator is greater than the electrical energy delivered to their site by National Grid during a billing period, then they shall receive a credit on the next bill, at the same rate per kWh as other customers. Remaining balances are carried to the next month's billing cycle.

  - For demand-metered customer-generators, excess kWhs generated are converted to the per kWh rate as indicated by the tariff and applied as a credit on the bill. Remaining credits will be converted back to their kWh values and carried to the proceeding billing month. Demand customers will be subject to applicable actual metered demand charges consumed in that billing period.

  - Any excess kWhs at the end of the 12-month period will be converted to a cash value and paid to the customer-generator by National Grid under the annual average avoided cost rate.

RG&E

Many of the regulations in the RG&E tariff mirror those in the Net Metering law and Standardized Interconnection Requirements (SIR), and the tariff mentions that customer-generators must refer to the PSC SIR guidelines.

The following requirements must be met for any customer wishing to participate in the Farm Waste Electric Generating System Option to become a net-metered customer under RG&E jurisdiction:

- The rated capacity of the farm waste generator cannot exceed 500 kW.

- Power must be generated by a minimum of 90% biogas produced from AD, on an annual basis.

- The digester feedstock must be 50% by weight livestock manure.

- Power can be put back on the grid on a first-come first-served basis, until the quota of power generated from solar and farm waste generation systems is reached, which is 16,250 kW, equal to 1% of RG&E's electric demand in the year 2005.

- In the event that the total rated generating capacity of electric generating equipment that provides electricity to RG&E through the same local feeder line exceeds 20% of the rated capacity of the local feeder line, the customer owning or operating such equipment may be required to comply with additional measures to ensure the safety of the local feeder line.

- RG&E will install appropriate metering devices for a net-metered customer, even if a second meter is determined to be needed, RG&E will pay for it. If RG&E determines it is necessary to install a transformer to protect the grid and other customers from power disturbances by the customer-generator delivering power back to the grid, the customer will be responsible for paying RG&E's costs of purchase and installation for the necessary equipment, up to $5,000 per farm operation.

- For time-differentiated rates (TOU meter), if RG&E provides more electricity to the customer-generator than the customer-generator delivers back to the grid, then RG&E will bill the customer for the net kWh supplied by RG&E during that billing period. This netting of kWh will occur each billing period.

- For time-differentiated rates (TOU meter), if the customer-generator delivers more electricity to the grid than RG&E provides to that same customer-generator in a billing period, then a kWh credit will be carried forward for the next billing period.

- For demand-billed customers, excess kWh the customer-generator delivers to the grid are converted to a dollar value and applied as a credit to the current bill. Any excess dollars remaining will be converted back to kWh and carried forward to the next billing period as a kWh credit.

- If the excess kWhs in each of the scenarios above are a positive balance at the end of a year, RG&E will give a cash payment to the customer-generator for the amount of excess kWhs times the average avoided cost for energy of the 12-month period.

- Regarding electric hybrid generating systems, any customer who owns/operates two types of electric generation systems (for example, a farm operates an AD system and generates electricity but also wishes to install a small wind turbine to produce electricity), an option is available to allow hybrid facilities to have the benefit of net metering. All customers desiring to operate a hybrid facility must comply with the PSC SIR guidelines.

Appendix 12 References:

New York State Electric & Gas. 2009. Rules, Regulations and General Information.

Niagara Mohawk Power Corporation. 2009. Schedule for Electric Service.

Rochester Gas and Electric Corporation. 2009. Electric tariff.